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COLLABORATORY AND TELECOMMUNICATIONS EXPERIMENTS

Northeast Parallel Architectures Center

Roman Markowski and Geoffrey Fox

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Rome Laboratory
Air Force Materiel Command
Rome, New York

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13. ABSTRACT (Maximum 200 words)

The objectives of this effort were to: 1) determine the appropriate distributed collaboration technologies for NYNet (an experimental, high speed network in New York State) applications; 2) prototype a Mosaic-based infrastructure for delivering collaboratory information; 3) implement collaborative technology within the area linked by the NYNet ATM (Asynchronous Transfer Mode) network; and 4) demonstrate the capabilities of the multimedia collaboratory technology over an ATM network by means of a telemedicine experiment. Chapter 2 of this report surveys the various video-conferencing and collaboratory solutions available from August 1994 to August 1995. The next chapter describes the Mosaic-based information server, caching technology, and Web-Oracle interface. Chapter 4 provides a description of the ATM cluster built and used during the project at the Northeast Parallel Architectures Center located in Syracuse University. Chapter 5 discusses research topics associated with telemedicine applications, including the Distributed Pathodology Workstation. Desktop collaboration and compression technologies are included in the appendices.

14. SUBJECT TERMS

Videoconferencing, Distributed collaboration, Asynchronous transfer mode, Distributed information server, Multimedia applications, Telemedicine

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CONTENTS

1 Introduction

This document describes the findings of a 12 month research effort (August, 1994 to August 95) entitled **"Collaboratory and Telecommunications Experiments"**. The project was funded by Rome Laboratory (contract number F30602-94-C-0133) located at the Griffiss Air Force Base in Rome, New York.
Objectives and scope of the effort were defined as follows:

- Determination of appropriate **collaboratory** (distributed collaboration) technologies for NYNET applications
- Prototype of **Mosaic-based** infrastructure for delivering collaboratory information (simulation on demand, caching service)
- Development of collaborative technology within the area linked by the **NYNET ATM network**
- Demonstration of the capabilities of the multimedia collaboratory technology over an ATM network **(telemedicine experiment)**

The material in this document is presented in the following way: **Chapter 2** ("Collaboratory Technology Evaluation and Benchmarking") surveys the various video-conferencing and collaboratory solutions available on the market from August 1994 to August 1995. **Chapter 3** ("Project Information Server") describes the Mosaic-based Information Server, caching technology and Web-Oracle interface. **Chapter 4** ("NYNET Support for Information Services") provides a description of the ATM (Asynchronous Transfer Mode) cluster built and used during the project in NPAC - Northeast Parallel Architecture Center at Syracuse University. **Chapter 5** ("Telemedicine Experiment") discusses research topics addressed by the project in the area of telemedicine applications including the Distributed Pathology Workstation. **Appendices** include tutorials on Desktop Collaboration and Compression Technologies. Chapters 2-5 cover the 4 major tasks defined in the project.

2 Collaboratory Technology Evaluation and Benchmarking

2.1 Objectives

- Evaluation and Benchmarking of several commercial and public domain collaborative technologies
- Installation of selected 1-3 products in various places over NYNET.
- Indepth evaluation of selected packages including both basic functionality and the ability to link with data processing modules.

2.2 Desktop Videoconferencing Products

Early video conferencing utilized large pieces of expensive equipment to provide "room" based video conferencing. The paradigm for room based video conferencing is that participants at a site all gather together in a specially equipped conference room around a conference table and look at monitors displaying similar rooms at remote sites. Desktop video conferencing is a new paradigm for video conferencing. It is "desktop" based. The scheme for desktop video conferencing is that participants sit at their own desks, in their own offices and call up other participants using their personal computer in a manner much like a telephone.

Desktop video conferencing is a form of connection via the communication channel limitted by available bandwidth. There are two methods of solving the bandwidth bottleneck problem. Most video conferencing packages use both to some varying degree. One solution is to use a communications channel with more bandwidth than a telephone line, e.g. Integrated Services Digital Networks (ISDN), still the best choice for long distance networking.

Another method uses compression technologies. There are many compression algorithms. The ITU/CCITT has created an international standard called H.261. H.261 is a very good compression algorithm and it performs very well. Unfortunately,

it is also very computationally intensive and as such generally requires special purpose hardware for your computer in order to use it. Because, of this many companies have created their own proprietary algorithms. Interoperability is still a big issue in industry and each company is striving to make their method standard.

Desktop videoconferencing systems are catching on, with vendors reporting booming growth rates. Last year (1994), desktop videoconferencing vendors shipped 30,000 units and they expect to ship 90,000 units this year and 300,000 next year (Network World, June 19,1995, p49). The systems are gaining popularity as prices fall and users realize the benefits of conferencing from their desktop computers, where most of their day-to-day business tools are stored or accessible. However, desktop systems cannot currently replace room or rollabout systems in video quality or group conferencing capabilities. The desktop videoconferencing market changes rapidly, with new products being announced almost every week. The market is still young and dynamic.

We have evaluated the basic functionality of the following collaboratory packages:

UNIX platform

- Communique Desktop Multimedia Videoconferencing (InSoft) [Sun, HP, IBM RS/6000, DEC Alpha AXP, SGI, 486/Pentium]
- Paradise Software Video Conferencing (Paradise Software, Inc.) [Sun]
- ShowMe (Sun Microsystem) [Sun]
- InPerson collaboratory package (SGI) [SGI]
- PictureWindow (BBN) [Sun]

MBONE software

- IMM Image Multicaster Client
- IVS Multihost audio/videoconferencing
- MMCC Multimedia Conference Control

- NEVOT audioconferencing tool
- NV videoconferencing tool
- SD Session Directory
- VAT audioconferencing tool
- LBL-WB whiteboard tool

IBM PC platform

- InVision (InVision Systems Co)
- Live PCS 100/50/LiveLAN (Picture Tel Co)
- Person to Person (IBM)
- ProShare Video System (Intel Co)
- Share Vision 3000 (Creative Labs)

MacIntosh

- Cameo Personal Video System V3.0 (Compression Labs)
- Connect 918 (NUTS Technologies Inc)
- CU-SeeMe videoconferencing tool (Cornell Uni)
- VISIT Video and Visit Voice (Northern Telecom, Inc.)
- Share View 300/3000 (ShareVision Technologies)

The online, more extended version of this survey is available on http://kopernik.npac.syr.edu:1200. In our study, we did not analyze large and expensive videoconferencing systems as CLI Eclipse 8100 installed in NPAC or another CLI communication device working in SUNY Health Science Center (HSC).

Following is a short description of some of the products investigated in alphabetical order:

Cameo Personal Video System

Provider: Compression Labs Inc.
Description: Video over Switched 56, ISDN, and Ethernet. Audio requires separate ISDN or analog phone line.
Platforms: Macintosh
Requirements: System 7 or higher, QuickTime, ISDN card for ISDN use, video card (RasterOps 24STV, 24LTV), Analog telephone or speakerphone.
Price: \$1595 without camera, \$2095 with camera.
Contact Info: Compression Labs Inc., 2860 Junction Ave., San Jose CA, 95134, USA, phone: +1.408.435.3000, toll free: 1-800-CALL-CLI.
Audio Encoding: Proprietary CLI PV2 compression algorithm
Video Encoding: Proprietary CLI PV2 compression algorithm
Multipoint: No
Collaboration Features: File Transfer.

Communique!

Provider: InSoft - http://www.insoft.com/
Description: Video/Audio/Tools over ISDN, Frame relay, FDDI, SMDS, Ethernet, ATM.
WWW: http://www.insoft.com/ProductOverview/C/C.html
Platforms:

Sun	SunOS 4.1.3, 4.1.4
Sun	Solaris 2.3, 2.4
HP	HP-UX 9.0.3, 9.0.5, 10.0
IBM	AIX 3.2.5, 4.1.1

DEC	OSF/1, OSF/2, OSF/3
SGI	IRIX 5.3
Intel PC	Windows 3.1, 3.11

Requirements: Video card and camera.

Price: $9495

Contact Info: InSoft, 4718 Old Gettysburg Rd. #307, Mechanicsburg PA, 17055, USA, phone: +1.717.730.9501, e-mail info@insoft.com

LAN Protocols: TCP/IP

Video Encoding: CellB, JPEG, Indeo - http://www.intel.com/IAL/indeo/indeo.html

Multipoint: Yes

Collaboration Features: Shared Whiteboard, Shared Applications, Shared Writeboard, File Transfer, Groupware Tools.

Notes: H.261, G.711 planned in future versions. Upon official release of Windows NT 3.51, Communique! will be available for NT both on Intel and Alpha based PC's.

<u>Connect 918</u>

Provider: Nuts Technologies

Description: Video/Audio/Tools over Analog, Switched 56, ISDN, or Ethernet.

Platforms: Mac

Price: $4000-$5900 depending on ISDN or LAN options.

Contact Info: Nuts Technologies, 2374 Walsh Ave., Santa Clara CA, 95051 USA, phone: +1.408.980.7800, Applelink: NUTS.USA.

Audio Encoding: G.711, G.722, G.728

Video Encoding: H.261

Interoperability Standard Support:H.320

Multipoint: No

Collaboration Features: Whiteboard, Screen sharing.

Notes: Reported not to be fully H.320 compliant yet (though product literature claims they are). PC version in the works.

CU-SeeMe

Version: 0.80 (Macintosh), 0.34 (PC).

Provider: Cornell University

Description: Video/Audio over the Internet. (PC version is video only).

WWW: ftp://cu-seeme.cornell.edu/pub/CU-SeeMe/html/Welcome.html

Platforms: Macintosh, PC.

Requirements: Video camera.

Mac: 68020 or higher, System 7 or higher, 16-level-grayscale display, MacTCP, video hardware (Video Spigot hardware or AV Mac), audio hardware, Quicktime.

PC: 386DX or higher, Microsoft Windows 3.1+, Windows Sockets compliant TCP/IP, 8 bit video driver, video hardware supporting Microsoft Video For Windows.

Price: Free, by anonymous ftp from ftp://gated.cornell.edu/pub/CU-SeeMe/

Contact Info: Dick Cogger, e-mail R.Cogger@cornell.edu, phone: +1.607.255.7566.

LAN Protocols: UDP/IP, IP Multicast.

Video Encoding: Non-standard

Multipoint: Yes, using Unix reflector software.

Collaboration Features: None

Notes: Future plans include operability with MBone and audio for the PC version. Most recent Mac version has a slide projector and a plug-in interface to support externally developed function modules (chat window coming soon).

InPerson

Provider: Silicon Graphics http://www.sgi.com/

Version: 2.0 (April 1995)

Description: Video/Audio/Tools over ISDN, T1, Ethernet, FDDI. A conference includes a shared whiteboard and a "shared shelf" for visual file transfer.

WWW: http://www.sgi.com/Products/inperson_main.html

Platforms: InPerson runs on any SGI platform with graphics. The SGI Indy comes

bundled with all the audio/video hardware/software you need. For machines without video hardware, a static image is used instead of live video. For machines without audio hardware, the InPerson whiteboard can be used with an analog phone line for voice. The InPerson whiteboard is available on Windows from NetManage (+1-408-973-7171, e-mail sales@netmanage.com. Internezzo Technologies (+1-415-464-0258) plans to provide InPerson on Suns and HPs by Dec. 1995.

Requirements: IRIX 5.3 system software. No additional hardware needed on Indy.

Price: $495 U.S. list

Contact Info: US toll free: 1-800-800-7441, e-mail inperson@sgi.com

LAN Protocols: Audio and video data is sent using UDP/IP. IP multicast is used for all conferences with more than two participants. The whiteboard uses TCP/IP.

Audio Encoding: InPerson supports several standard audio compression formats:

Intel/IMA DVI ADPCM	16 kHz	64 kbps(default)
Intel/IMA DVI ADPCM	8 kHz	32 kbps
CCITT/ITU-T G.711u-law PCM	8 kHz	64 kbps
GSM 06.10 RTE/LTP	8 kHz	13 kbps
uncompressed mono	44.1 kHz	706 kbps
CCITT/ITU-T G.728	8 kHz	16 kbps with optional hardware

Video Encoding: H.261, RGB8, HDCC (video compression algorithm developed at SGI)

Multipoint: Yes

Collaboration Features: Text, image, 3D model sharing. Whiteboard can include graphics, as well as text and images. Whiteboard in version 2.0 supports sharing 3D models among participants. InPerson also includes a "shared shelf" for visual file transfer between participants in a call. InPerson is part of Silicon Graphics' Mind-Share collaborative environment. This environment includes:

- interactive discussion of text, images, 3D models.
- software tools for digital media capture, creation, edit and playback.
- interactive presentation and authoring tool.
- store and forward of digital media and 3D documents.

- 3D support among all collaboration tools.

Notes: Optional hardware board for Indy provides G.728 audio compression and acoustic echo cancellation.

InVision

Version: 3.0

Provider: InVision Systems Corp.

Description: Video/Audio/Tools over LAN/WAN (including Ethernet, Token Ring, FDDI, Frame Relay, ATM, ISDN, etc.) Also V.32 or faster modem.

Platforms: PC

Requirements: 486/33 or faster, Microsoft Windows 3.1+, 8MB RAM, 3MB hard disk space, high density 3.5" disk drive, 256 color VGA or SVGA - local bus recommended, Windows-compatible mouse or pointing device, Wave compatible sound card, Video for Windows compatible compression board, camera and microphone.

Price: $595, includes software only.

Contact Info: InVision Systems Corp., 317 S. Main Mall, Suite 310, Tulsa OK, 74103, USA, toll free: 1-800-847-1662, phone: +1.918.584.7772, fax: +1.918.584.7775, Internet: info@invision.com, Compuserve: 72002,1677.

LAN Protocols: TCP/IP, IPX

Video Encoding: DVI (ActionMedia II or MediaShare Mambo)

Multipoint: Video is point to point, document conferencing up to 12 users.

Collaboration Features: Includes VisionGraphics document sharing software which includes a whiteboard and supports OLE.

Notes: H.261, H.320, MPEG under development.

IVS (INRIA Videoconferencing System)

Version: 3.5

Provider: RODEO Project, INRIA Sophia Antipolis, France.

Description: Video/Audio over the Internet.

WWW: http://zenon.inria.fr:8003/rodeo/personnel/Thierry.Turletti/ivs.html
Platforms: Various Unix platforms (see Requirements section).
Requirements: A workstation with a 1, 4, 8 or 24 bit screen depth. Multi-host conferences require kernel support for multicast IP extensions (RFC 1112). Video frame grabbers supported are:
SPARC stations with Parallax, SunVideo, VideoPix and the new Vigrapix
Silicon Graphics stations with IndigoVideo, GalileoVideo and VinoVideo
PC/Linux with SCREENMACHINE II
DEC 5000 stations with VIDEOTX
DEC ALPHA stations without video capture
PC/FreeBSD2.0 stations without video capture.
HP stations with VideoLive
No special hardware apart from the workstation's built-in audio hardware is required for audio. Requires a camera compatible with the video board.
Price: Free, by anonymous ftp from ftp://zenon.inria.fr/rodeo/ivs
Contact Info: http://zenon.inria.fr:8003/rodeo/personnel/Thierry.Turletti/me.html, e-mail Thierry.Turletti@sophia.inria.fr
LAN Protocols: UDP/IP, IP Multicast.
Audio Encoding: PCM, ADPCM, VADPCM
Video Encoding: H.261
Multipoint: Yes
Collaboration Features: None

nv (Network Video)

Version: 3.3 (beta)
Provider: Xerox/PARC
Description: nv provides unicast and multicast video over the Internet. It is commonly supplemented with vat (Visual Audio Tool) and wb (Whiteboard) for full-featured video/audio conferencing and collaboration.
Platforms: Sun SPARCstation, DECstation 5000 and Alpha, SGI, HP9000, IBM

RS6000.

Requirements: Receivers need no special hardware - just an X display. Senders require a camera that is compatible with the video capture hardware:

Sun/SunOS 4: Parallax, PARCVideo, VideoPix, X11.

Sun/SunOS 5: SunVideo, VideoPix, X11.

DEC 5000/Ultrix: PIP, X11;

DEC Alpha/OSF 1: J300,X11;

SGI/Irix 5: SGI VL (Indy, Galileo), X11.

HP9000/HPUX: VideoLive, X11.

RS6000/AIX: IBM VCA, X11.

Price: Free, available at ftp://parcftp.xerox.com/pub/net-research

Contact Info: Ron Frederick, e-mail frederick@parc.xerox.com

LAN Protocols: UDP/IP, IP Multicast.

Audio Encoding: N/A

Video Encoding: Native NV, CU-SeeMe, Sun CellB

Multipoint: Yes

Collaboration Features: None

Notes: nv, vat, and wb are tools commonly used with MBone. vat and wb are available at ftp://ftp.ee.lbl.gov/conferencing/. An on-line paper about nv is available in ftp://parcftp.xerox.com/pub/net-research/nv-paper.ps

<u>Person To Person</u>

Version: 1.0

Provider:IBM http://www.ibm.com/

Description: Video/Tools over Analog, ISDN, Ethernet, or Token Ring. Audio requires separate ISDN or Analog phone line.

Platforms: PC

Requirements: 386SX minimum, OS/2 2.x or Microsoft Windows 3.1+, 8MB memory, ActionMedia II hardware. Camera.

Price: $280

Contact Info: e-mail: p2p@vnet.ibm.com, phone: +1.404.238.6726, fax info: 1-800-IBM-4FAX (in US) +1.415.855.4329 (outside US).
LAN Protocols: NetBIOS, TCP/IP, APPC, Novell IPX/SPX.
Video Encoding: DVI
Multipoint: Yes
Collaboration Features: Whiteboard, File transfer, Talk window, Shared clipboard.
Notes: Information on the Web: http://www.hursley.ibm.com/~p2p and http://fiddle.ee.vt.edu/succeed/p2p.html.

<u>PictureTel Live PCS 100</u>

Provider: PictureTel
Description: Video/Audio/Tools over Switched 56, ISDN.
Platforms: PC
Requirements: 386 or higher, 2 ISA slots, Microsoft Windows 3.1+.
Price: $4995
Contact Info: PictureTel Corp., The Tower at Northwoods, 222 Rosewood Dr., Danvers MA, 01923, USA, phone: +1.508.762.5000, toll free: 1-800-716-6000, fax: +1.508.762.5245.
Audio Encoding: G.721, G.722, G.728, PT 724 proprietary algorithm
Video Encoding: H.261
Interoperability Standard Support: H.320
Multipoint: Yes (maximum of 16 parties).
Collaboration Features: Whiteboard, File Transfer, Screen sharing, Application Sharing.
Notes: Supports network speeds up to 384kbps.

PictureTel Live PCS 50

Provider: PictureTel
Description: Video/Audio/Tools over ISDN.
Platforms: PC
Requirements: 386 or higher, 1 ISA slot, Microsoft Windows 3.1+, VAFC graphics connection (available from PictureTel).
Price: $2495
Contact Info: PictureTel Corp., The Tower at Northwoods, 222 Rosewood Dr., Danvers MA, 01923, USA, phone: +1.508.762.5000, toll free: 1-800-716-6000, fax: +1.508.762.5245.
Audio Encoding: G.721, G.722, G.728, PT 724 proprietary algorithm
Video Encoding: H.261
Interoperability Standard Support: H.320
Multipoint: Yes (maximum of 16 parties).
Collaboration Features: Whiteboard, File Transfer, Screen sharing, Application Sharing.

PictureTel LiveLAN

Provider: PictureTel
Description: Video/Audio/Tools over Local Area Network.
Platforms: PC
Requirements: 486-66+, video capture card, Microsoft Windows 3.1+, camera, audio card, speakers, microphone.
Price: $395
Contact Info: PictureTel Corp., The Tower at Northwoods, 222 Rosewood Dr., Danvers MA, 01923, USA, phone: +1.508.762.5000, toll free: 1-800-716-6000, fax: +1.508.762.5245.
LAN Protocols: IPX
Audio Encoding: Proprietary

Video Encoding: Proprietary

Multipoint: No.

Collaboration Features: Application Sharing.

PictureWindow

Version: 1.4

Provider: BBN - http://www.bbn.com/

Description: Video/Audio over the Internet.

Platforms: Sun SPARCstation.

Requirements: Sun SPARCstation (1,1+,2,IPX,10), 8 bit color or grayscale frame buffer, 24MB memory, SunOS 4.1.1 or later with IPC_SHMEM option, OpenWindows 2.0 or higher or X11 R4 or higher with an 8-bit PseudoColor visual, VideoPix card.

Price: $495 software only, $1495 with VideoPix and camera.

Contact Info: BBN, 150 Cambridge Park Drive, Cambridge MA, 02140, USA, +1.617.873.2000, toll free: 1-800-422-2359, fax: +1.617.873.5011, e-mail picwin-sales@bbn.com

LAN Protocols: UDP/IP, TCP/IP.

Multipoint: Yes

Collaboration Features: None

Notes: A receive-only demo is available through ftp at picwin.bbn.com (login as "picwin").

ProShare Video System 150

Version: Video System 150 - http://www.intel.com/comm-net/proshare/prosh150/

Provider: Intel - http://www.intel.com/

Description: Video/Audio/Tools over LAN

WWW: http://www.intel.com/comm-net/proshare/

Platforms: PC

Requirements: PC with Intel486(tm) 33 MHz CPU minimum, IntelDX2(tm) 66 MHz processor or Pentium(tm) processor recommended. Windows 3.1 or 3.11. 8 MB RAM minimum, 16 MB RAM recommended, plus 16 MB hard disk space (minimum). VGA display with 256 colors or higher (no feature connector required). Network interface card. 1 full-length ISA slot. Supported protocol stacks, at least one of:
IPX: Novell VIPX, version 1.11, 1.17, 1.18
TCP/IP: FTP PC/TCP, version 2.31, FTP OnNet, version 1.1
Novell LAN WorkPlace for DOS, version 4.12
NetBIOS:Microsoft Windows for Workgroups, version 3.11
LANDesk Personal Conferencing Manager software installed on your LAN
Price: $1499, includes software, one full length ISA card, color CCD camera, headset/microphone unit.
Contact Info: Intel Corp., 2200 Mission College Blvd., P.O. Box 58199, Santa Clara CA, 95052-8119, USA, phone: +1.503.629.7354, toll free: 1-800-538-3373, fax: 1-800-525-3019.
LAN Protocols: NetBIOS, TCP/IP, IPX (LAN physical layer independent: Ethernet, Token Ring, FDDI, T-1, Frame Relay)
Audio Encoding: GSM
Video Encoding: Indeo - http://www.intel.com/IAL/indeo/indeo.html
Collaboration Features: Whiteboard, application sharing.

ProShare Video System 200

Version: Video System 200 - http://www.intel.com/comm-net/proshare/prosh200/
Provider: Intel - http://www.intel.com/
Description: Video/Audio/Tools over LAN/WAN/ISDN.
WWW: http://www.intel.com/comm-net/proshare/
Platforms: PC
Requirements: PC with Intel486(tm) 33 MHz CPU minimum. IntelDX2(tm) 66 MHz or Pentium(tm) processor recommended. Windows 3.1 or 3.11. 8 MB RAM minimum, 16 MB RAM recommended, plus 17 MB hard disk space (minimum).

VGA display with 256 colors or higher (no feature connector required). 2 full-length ISA slots. For ISDN use NT-1 adapter ISDN telephone service from local phone company. For LAN/WAN use network interface card and supported protocol stacks, at least one of:

IPX: Novell VIPX, version 1.11, 1.17, 1.18

TCP/IP: FTP PC/TCP, version 2.31, FTP OnNet, version 1.1

Novell LAN WorkPlace for DOS, version 4.12

NetBIOS: Microsoft Windows for Workgroups, version 3.11

LANDesk Personal Conferencing Manager software installed on LAN

Price: $1999, when user purchases either local ISDN Service from a participating LEC or long distance ISDN Service from an IXC, the price drops to $1499. When purchasing *both* local and long distance ISDN service from participating carriers, the price drops to $999). Includes software, 2 full length ISA cards, color CCD camera, headset/microphone unit.

Contact Info: Intel Corp., 2200 Mission College Blvd., P.O. Box 58199, Santa Clara CA, 95052-8119, USA, phone: +1.503.629.7354, toll free: 1-800-538-3373, fax: 1-800-525-3019.

LAN Protocols: NetBIOS, TCP/IP, and IPX

Audio Encoding: GSM, G.711

Video Encoding: Indeo - http://www.intel.com/IAL/indeo/indeo.html, QCIF H.261

Interoperability Standard Support: H.320

Multipoint: Yes, using H.320-compatible bridges.

Collaboration Features: Whiteboard, application sharing.

PSVC (Paradise Software Video Conferencing)

Version: 2.1

Provider: Paradise Software, Inc. - http://www.paradise.com/

Description: Audio/Video/Tools over ISDN, Ethernet, ATM.

Platforms: Sun SPARCstation

Requirements: Parallax XVideo/PowerVideo boards, SunOS 4.1.3 or Solaris 2.3,

OpenWindows 3.x, 1MB disk space, 16MB memory, 16 MB swap.

Price: $995 (without any hardware)

Contact Info: Paradise Software, Inc., 7 Centre Drive, Suite 9, Jamesburg NJ, 08831, USA, phone: +1.609.655.0016, fax: +1.609.655.0045, e-mail support@paradise.com

LAN Protocols: TCP/IP

Video Encoding: M-JPEG

Multipoint: Yes

Collaboration Features: Whiteboard, Video Mail, Screen Capture.

Notes: Support for HP 700 series, Motif forthcoming. PSVC is integrated into Paradise Software's new "Simplicity" virtual meeting software. Paradise Software Products WWW Page - http://www.paradise.com/productinfo/Productinfo.html

<u>ShareVision Mac 3000</u>

Provider: Creative Labs http://www.creaf.com/

Description: Audio/Video/Tools over Analog phone line.

Platforms: Macintosh

Contact Info: Creative Labs, Inc., 1901 McCarthy Boulevard, Milpitas CA, 95035, USA, phone: +1.408.428.6600, toll-free: 1-800-998-1000, fax: +1.408.428.6611, AppleLink: SHAREVIS.MKT.

Price: $1299

Interoperability Standard Support: Future versions will support the ITU-T H.324 standards which are expected to be ratified in November 1995.

Notes: Interoperable with ShareVision PC product.

<u>ShareVision PC 3000</u>

Provider: Creative Labs - http://www.creaf.com/

Description: Audio/Video/Tools over Analog phone line.

WWW: http://www.creaf.com/www/products/video/svpc3000.html

Platforms: PC

Requirements: 486SX/33MHz (486DX/66MHz recommended), 2 available 16-bit ISA bus slots, 8MB RAM, 6MB hard disk space, Windows 3.1, VGA or SVGA display (16-bit or 24-bit VGA display card recommended).

Price: $1599, includes software, 2 boards (Video Blaster RT300 video capture/compression card and ShareVision PC Audio card), color CCD camera, fax/modem, headset/microphone.

Contact Info: Creative Labs, Inc., 1901 McCarthy Boulevard, Milpitas CA, 95035, USA, phone: +1.408.428.6600, toll-free: 1-800-998-1000, fax: +1.408.428.6611.

Audio Encoding: VATP

Video Encoding: VATP

Interoperability Standard Support: Future versions will support the ITU-T H.324 standards which are expected to be ratified in November 1995.

Multipoint: No.

Collaboration Features: Application sharing, Whiteboard, Document sharing, File transfer.

Notes: Interoperable with ShareVision Mac product.

<u>ShowMe</u>

Version: 2.0.1

Provider: Sun Microsystems - http://www.sun.com/

Description: Video/Audio/Tools over the Internet.

WWW: http://www.sun.com:80/cgi-bin/show?products-n-solutions /sw/ShowMe/index.html

Platforms: Sun SPARCstation

Requirements: Solaris 2.3 or later, X11 R5, OpenWindows 3, 1 SBUS slot, SunVideo board, SunMicrophone.

Price: $3270, including SunVideo board and camera. Educational discount available.

Contact Info:

e-mail sunsol-www@sunsolutions.eng.sun.com, toll free: 1-800-873-7869.

LAN Protocols: UDP/IP, TCP/IP, IP Multicast, RTP.

Audio Encoding: G.711 (uncompressed 8-bit, 8 KHz audio bit stream at 64 Kilobits per second)
Video Encoding: CellB
Interoperability Standard Support: No
Multipoint: Yes, with and without IP Multicast.
Collaboration Features: Whiteboard, Application Sharing for X11 R4/R5-based applications and Wabi 1.0 supported MS Windows applications.

VISIT Video

Version: 2.0
Provider:Northern Telecom Inc.- http://www.nortel.com/
Description: Video/Tools over ISDN or Switched 56. Audio requires separate ISDN or Analog phone line.
WWW: http://www.nortel.com/english/interop/vvideo.html
Platforms: PC, Macintosh.
Requirements:
PC: 386 minimum and hard drive, Microsoft Windows 3.1+, AT-bus expansion slot, DOS 5.0 or greater, 8MB RAM (12 MB RAM max on ISA PC, 16MB or more possible on EISA w/ memory re-mapping), 256-color VGA board and color monitor (Super VGA w/ thousands of colors support recommended).
Mac: Macintosh II family or other NuBus-equipped Apple computer, NuBus expansion slot, System 7 or greater, 8MB RAM, Color monitor. Camera included with product.
Price: $5319
Contact Info: Northern Telecom Inc., 2221 Lakeside Blvd., Richardson TX, 75082, USA, +1.214.684.5930, toll free: 1-800-667-8437, fax: +1.214.684.3866.
Video Encoding: H.261
Interoperability Standard Support: Future versions promise H.320 compliance.
Multipoint: No
Collaboration Features: Whiteboard, File transfer.

2.3 Evaluation of Selected Packages

We have chosen the following three videoconferencing products for further, indepth evaluation:

- Communique Desktop Multimedia Videoconferencing (InSoft) [Sun, HP, IBM RS/6000, DEC Alpha AXP, SGI, 486/Pentium]
- InPerson collaboratory package (SGI) [SGI]
- ProShare Video System (Intel Co) [IBM PC]

Communique has been installed and tested in
- NPAC - on Sun IPX (SunOS 4.1.3), Sun 10 (SunOS 4.1.3), SGI Indy (IRIX 5.3)
- Rome Laboratory
- Columbia University
- SUNY HSC

InPerson has been installed on SGI Indy workstations in
- NPAC
- Rome Laboratory
- Fowler High School
- Rome Free Academy
- Whitesboro Middle School

ProShare has been tested on IBM PCs installed in
- NPAC
- SUNY HSC
- NYNEX

2.3.1 Communique! - Desktop Multimedia Videoconferencing

Producer / author

InSoft, Inc.
4718 Old Gettysburg Road, #307

Mechanicsburg, PA 17055
Phone: 717-730-9501
Fax: 717-730-9504
E-mail: support@insoft.com
www : http://www.insoft.com

Information source

InSoft Communique! for SunOS 4.1.3 Administrator's Guide
InSoft Communique! OpenLook User's Guide
support@insoft.com
http://www.insoft.com/ProductOverview/C/C.html

Product description

Communique! is a workstation based product that integrates the multimedia aspects of graphics, audio, video, text and native application files into a virtual conference. It contains a suite of easily managed iconic tools for defining and initiating an on-line, real time conference with fellow workgroup members. Audio Conferencing, Video Conferencing, a Shared White Board, and a Shared Text Tools are just some of the tools available to the conference attendees. Communique is based on a core software architecture called Digital Video Everywhere (DVE). DVE is an open system platform. It allows users to communicate between various InSoft supported host desktop systems, transparently interoperate across TCP/IP, ethernet, ATM, FDDI, Frame Relay, SMDS and ISDN, and simultaneously supports video compression standards such as JPEG, MPEG, CellB, Indeo and H.320.

Hardware and software requirements

- SPARC desktop workstation connected to a TCP/IP-based network
- Minimum of 24MB of RAM
- Minimum of 60MB of swap space

- 20MB of disk space for the application
- 5MB-10MB of temporary disk storage for file transfers
- Color display
- Optional hardware
  - High-quality microphone for audio conferencing
  - Video capture card - some functions of Communique! may be restricted by the video capture card you are using
    * Parallax XVideo 24SVC and XVideo 24SCV-VIO
    * Parallax PowerVideo
    * RasterOPs SPARC Card TV II
    * SMCC VideoPix
- OpenWindows 3.0 or Motif 1.1 (or higher) windowing environment for SunOS 4.1.3
- Communique! License Key(s) and Software package

Specifications

- There are several versions of Communique! software:
  - IBM RS 6000/ AIX
  - HP 9000/700
  - DEC Alpha/ OSF/1
  - Sun workstations/ SunOS 4.1.3 and Solaris 2.3 (OpenWindows 3.0 and Motif 1.1)
  - SGI/IRIX 5.3

- The Motif version of Communique! software gives much better performance than the OpenWindows version. Parallax video under Motif features optimized routines significantly increase performance speed. Frame rates can be doubled by this enhancement. Communique! for Parallax running under Motif automatically uses the optimized video routines.

- Version 3.2 of Communique! does not interoperate with earlier versions.

- Communique! can handle 24-bit and 32-bit raster files in all tools.

- Open Windows users under SunOS 4.1.3 need to install the Parallax Xvideo Toolkit for SBus systems version 3.0.6 or higher (X11R4 environment). Motif users under SunOS 4.1.3 need to install the Parallax XVideo Toolkit for SBus systems version 1.1 or higher (X11R5 environment)

- Every person running Communique! can receive video from fellow conference members, but you must have a video capture card installed in your workstation to send video.

- InSoft uses the FLEXlm package for license management of Communique using license keys. These license keys can either be "floating" or "node-locked". A floating license allows any user on the network to use the software, up to specific number of users (one workstation must be designated as the License Server). A node-locked license is created for a specific workstation and allows only that workstation to access the licensed software.

- Communique! functions very well with ATM cards such as Fore Systems SBA 200 ATM adapter.

- The following tools are available for conference members: - audio tool - text tool - shared write board - graphics tool - shared white board - video tool - TV tool - file exchange tool - SHARE application tool

- SHARE is an optional tool that is not included with the basic Communique! package

- You can hold a conference with up to **nine** other persons
- Using Parallax Xvideo or Power Video, Communique! allows you to controll bandwidth usage. TV Tool interface reports the approximate frames displayed per second and bandwidth consumed by the active TV Tool.

Basic functionality

- **audio :** YES
- **video :** YES
- **white board :** YES
- **application sharing :** YES
- **background file transfer :** YES
- **audio echo cancellation :** YES

Pricelist (August 1995)

Communique Conference Kit CK-CCDH-PV Node Locked license w/audio, text, graphics, shared workspace and video support, Parallax Power Video SBus card, CCD camera, Microphone	$9495.00
Communique Annual Maintenance CKM-CCDH-PV Software Documentation and Upgrades, Parts and labour warranty on Video Board, camera and microphone for one year	$950.00
SHARE Application Resource Env C-001-SHARE	$595.00
SHARE Annual Maintenance Documentation and Production Upgrades for one year	$107.00

Results of tests (ver 3.0, 3.1, 3.2.1, 4.0)

Configuration

The Communique! software is installed on the following workstations in NPAC:
Sun IPX and Sun10 (32 MB RAM, 1GB HDD, Parallax XVideo SBus 24SVC SunOS 4.1.3, OpenWindows 3.0, Color display)
SGI Indy (32 MB RAM, 1GB HDD, IRIX 5.3)

Analysis of basic functionality

- AUDIO TOOL The Audio Tool controls the various audio aspects of the Communique! session. The Audio Panel contains several controls for the Sending Volume, Playback Volume, Local Monitor Volume, Audio Compression, Silence Sensor level, Mute, A/V Sync, Output Device (speakers or headphones), and Echo Cancellation.

- TEXT TOOL The shared text tool allows users to distribute notes and text to the conference members. The received notes can be saved to disk or discarded. There are 3 ways to prepare the text you wish to distribute among the members of the conference: the text can be typed, the file can be loaded using Load option from File menu or the textual file icon can be dragged and dropped into Drop Site.

- SHARED WRITE BOARD TOOL This is a tool for text-only coferencing. It allows users to carry on a textual conversation using just their keyboard. The entire transcript can then be saved as a record of the meeting.

- GRAPHICS TOOL It allows users to capture and send still graphic images to other conference participants. The tool is useful for displaying charts, graphs, images and 'snapshots' from the screen. The received image can be dismissed or saved. There are 4 methods to prepare images for distrubution among conference participants:
  - Load Image (File menu)

- QuickPic (camera icon)
- Launch standard snapshot tool (window, screen, region)
- Drag and Drop raster file into DropSite

- SHARED WHITE (RASTER) BOARD This tool allows to draw, erase, mark up images from other programs, etc., in real time while all members of the conference look on. You can:
  - Load raster file (File menu)
  - QuickPic (camera icon)
  - Launch standard snapshot tool (window, screen, region)
  - Drag and Drop raster file into DropSite
  - choose width and color of lines
  - choose font, size, style and color of text
  - erase image or markups
  - save (entire or part) or print the whiteboard
  - clear markups or entire whiteboard

- VIDEO TOOL If you have a video capture card you can use the Video Tool to create graphic images from a digital camera or a video tape. The Video tool allows you to work with any video input to capture still video images to be shared as graphics in the conference. You can choose window size (full, 1/4, 1/16) and image distribution tool.

- TV TOOL The TV Tool enables Communique! users to conduct a real-time Video Conference from their desktop.

- INFORMATION EXCHANGE TOOL With the Information Exchange Tool, you can transfer any type of data file to all or selected users of a conference. You can pick a file from the File menu or drag-and-drop files directly from the File Manager. It also allows you to receive information coming from other participants.

- SHARE APPLICATIONS TOOL Share Application Resource Environment is an optional feature of InSoft's Communique! which allows conference members

to "share" an application window. To SHARE local applications, a SHARE license key is required (ISHARE server). To receive a shared application (SHARE client), any version of Communique! will work and no license key is required. Almost any application can be shared across a conference. However, applications written with xview calls may not allow remote users to type into the application.

Performance tests

The initial tests were performed on two Sun IPX workstations with Parallax Video cards and SBA 200 ATM adapters. Each workstation had 2 interfaces : ethernet and ATM. We have measured the time required to transfer two images (image1.ras = 305.173 B; image2.ras = 1.037.030 B) between workstations using Shared White Board and Graphics Tool. We have also measured performance of Video Tool, TV Tool and Audio Tool.

- **Shared White Board and Graphics Tool**

	ATM	ethernet	load time
image1.ras	25 sec	23 sec	14 sec
image2.ras	70 sec	60 sec	40 sec

- **Video Tool**

	ATM	ethernet	compress
full window	25 sec	15 sec	6 sec
1/4 window	8 sec	6 sec	3 sec
1/16 window	4 sec	4 sec	1.5 sec

- **TV Tool**

	ATM	ethernet
full window 640x480	10.1 fps 1005 Kbps	10.8 fps 1080 Kbps
1/4 window 320x240	15.0 fps 554 Kbps	15.9 fps 557 Kbps
1/16 window 160x120	20.1 fps 256 Kbps	19.9 fps 242 Kbps

- **SHARE Application Tool**
  - Each SHARE server can launch only one application at the conference time
  - All conference participants receive the application (xclock,xv,xterm, etc)
  - No form of access control is implemented (all participants can edit a file at the same time)
  - We can change the position of a window - it affects other user windows
  - Each conference member sees only his or her mouse pointer
  - Only fully X-based applications can be shared (incompatible windowing technologies: SunView, NeWS, Phigs, Display Poscript)

- **Audio Tool** The performance of audio is much better when we are using ATM communication between videoconference participants. The best audio quality can be obtained when:
  - the person speaking directs their voice towards the microphone and from no more than a foot away
  - silence sensor should not be too high
  - A/V Sync Threshold should not be too high

- echo - the voice is picked up from a remote user's speaker by the remote microphone and retransmitted into the conference. This effect can be removed by using headphones, keeping speakers away from the microphone or by increasing the echo cancellation.

The best quality of audio signal was obtained with the following audio parameter values:

parameter	range	NPAC-RL	Factory
Sending volume	0 - 100	47	24
Compression	dis/enabled	disabled	enabled
Playback volume	0 - 100	51	65
Loc.monitor vol	0 - 100	0	0
A/V Sync	0 - 10	1	10
Silence Sensor	on/ off	on	on
Sensor Level	1-6144	2950	2048
Echo cancellation	0 - 4	2	2

2.3.2 InPerson - Desktop Conferencing for SGI Workstations

Producer / author

Silicon Graphics, Inc
2011 N.Shoreline Blvd.
Mountain View, CA 94043
phone: (415) 390-1445
fax: (415) 390-6218
http://www.sgi.com/

Information source

InPerson Setup and Administration Guide

InPerson User's Guide

man inperson

BYTE, November 1994, page 237

http://www.sgi.com/Products/inperson_main.html

Product description

InPerson is a multimedia desktop conferencing tool for SGI workstations such as the Indy, Indigo and Indigo2. Each conference includes audio and either video or a static image of the participant. Use of shared whiteboard and shared shelf is optional on a per-conference basis. Systems that lack audio and/or video hardware can still use the shared whiteboard. Before you can begin using InPerson, you need to install a license key.

Hardware and software requirements

- SGI workstation
- IRIX 5.3 operating system
- Multicast routing or tunnelling for multiway conferences

Specification

- You can place a conference on hold or you can look and listen to a conference without transmitting any audio and video. This allows you to simultaneously work on urgent projects while monitoring the progress of a conference. This also allows you to hold a private conversation in your office without disturbing the ongoing conference.
- Each conference can have 2 to 6 participants when using Indy SC models. Due to the use of multicasting, total network bandwidth usage scales linearly with the number of participants (multicast addresses range from 224.0.0.0 to 239.255.255.255). The InPerson product consists of several programs: the phone, the conference view, and the whiteboard. The InPerson program is

the phone tool that you see on your desktop. The view program opens the main conference window. It manages all audio and video actions, the shared shelf, and the whiteboard. The whiteboard program is opened by the view when a user asks to open it. These two programs are started on behalf of the user by the inperson program.

- The program supports H.320 audio codec
- The file transfer is based on the file icon dragging/dropping scheme
- Frame rate adjustments range :1-20 fps (default 15fps)
- Video window size: small 160x120, max 320x240 pixels
- Audio sampling rate adjustment available (default 16KHz)
- Bandwidth use indicator is provided
- Video on-hold/privacy feature available
- InPerson uses the Interactive Multimedia Association/Intel DVI compression algorithm for audio. By default, InPerson samples the audio at 16KHz and compress the data, so it consumes up to 64 Kbps.

Basic functionality

- **audio :** YES
- **video :** YES
- **white board :** YES
- **application sharing :** NO
- **file transfer :** YES
- **echo cancellation :** YES

Pricelist

October 1994 $495.00

Results of tests (ver 1.0, 1.1, 2.0b, 2.0a, 2.0)

Configuration

The InPerson software is installed on SGI Indy (32 MB RAM, 1GB HDD, IRIX 5.3, Color display)

Analysis of basic functionality

- **Placing and Reciving Calls** To place or receive calls, you must run the inperson program. To run inperson, double-click its icon from the Icon Catalog's Applications page or type in a shell:
  % inperson

  When you run inperson, the image of an old-fashioned telephone appears on your desktop. The phone rings and flashes when someone is calling you. To answer a call, place the cursor over the phone; then click the left mouse button. To make a call, drag group or user icons over the phone image and release the mouse button.

- **Multicast** A multiway conference includes three or more systems, some of which may be located on different networks. If you have SGI systems as routers, you have to turn on multicast routing using mrouted. If you have routers that do not support multicast, you have to create tunnels between the networks. The multicast packets are encapsulated inside unicast packets and sent to the other end of the tunnel.

- **Participating In a Conference** The conferencing window appears when you participate in a call. By default, it displays a video of each person participat-

ing in the conference. Participants on systems that do not support video are represented by a static image. The conferencing window can expand to show two other regions - the white board and the shelf. To open the whiteboard, choose "Open whiteboard" from the Call menu. To open the shelf, choose "Open shelf" from the Call menu.

- **About the Whiteboard** The whiteboard is similar to the whiteboard or chalkboard you might find in a conference room. Each person in the conference has a unique marker that she or he can use to sketch or write notes on the board. People can also take screen and video snapshots and place them on the board. The toolbar along the left edge of the whiteboard page has tools for drawing, typing, taking snapshots, selecting colors, text styles, and line styles, and adding new pages. The contents of the whiteboard can be stored as "whiteboard" file or EPS file.

- **About the Shelf** The shelf is similar to the shelves that are used within the Indigo Magic user environment. Files placed on the shelf are instantly accessible to all persons in the conference. You can bring the file to the local file system by clicking on and dragging the icon from the shelf to a file manager view of one of the local directories. Dragging the icon to the desktop puts only a link to the file on the desktop. The actual file may not be accessible later so if you want to save the file, drag the file icon to a local directory. You can double-click over an icon on the shelf to open it, as with any Indigo Magic icon. If the icon is a folder, a directory view is launched for that folder. For any other category of icon, you may be notified that InPerson does not know how to run that application shared between the conference participants and asked if you want to run it standalone. When InPerson is unable to access a file via NFS, it makes a local temporary copy of the file in a shadow directory so as to preserve all of the file operation semantics of Indigo Magic icons. All temporary copies and the shadow directory are removed at the end of a call. The location of the shadow directory is controlled by an X resource. The shelf will only allow you to drop files which are local to your own system.

- **Customization** There are two control panels that let you set preferences to customize the behavior of the phone and of a running conference. You can also save the preferences as the default for future calls into the inperson file in the the $HOME/.desktop-'hostname' directory. To access the phone's control panel, place the cursor over the phone, and then press the right mouse button. Choose "Control Panel..." from the menu bar that appears. The "Save" button saves the preferences into the inperson file. The "OK" button applies the preferences to future incoming and outgoing calls. The Video section controls whether InPerson uses video in calls. If set to "Live", InPerson will will capture and transmit video if video hardware is available. If set to "Static Image", InPerson will always use a static image in place of video. The most common reason to change this setting to "Static Image" is to decrease the network bandwidth required for a call. The InPerson Call window also provides a control panel that you can use to monitor or modify the characteristics of the call in progress.

- **Resources** There are some additional preferences that control the behavior of InPerson that are not on the control panels. Advanced users can change these resources by editing the InPerson user configuration file. The default X11 resources file /usr/lib/X11/apps-default/InPerson contains a few resources that can be customized at the beginning of the file. You can edit this file as root to make changes for all users on the system. If you want your private customizations, copy the file to $HOME/.desktop-'hostname'/InPerson, then following the instructions at the beginning of the file.

  InPerson*keyFrameInterval (Video key frame interval)
  This resource controls how often a complete video frame is sent. Normally, HDCC compression just sends the portion of the video frame that changed. Periodically, HDCC sends out the complete video frame, regardless of whether or not it has changed. If a network packet containing compressed video is lost, that portion of the image will not be updated until it changes again or until the next key frame is sent. Default value is 15 seconds; range is 1-100 sec-

onds. Most common reason to decrease this resource from the default value is to improve image quality on a network with a high packet loss rate. Most common reason to increase this resource from the default value is to decrease the network bandwidth required for video.

InPerson*audioEncoding (Audio encoding scheme)
This resource specifies the sampling rate and the compression scheme for audio. The values are "idvi16" (the default), "idvi8", "ulaw", "gsm", "uncomp32" and "uncomp44".

InPerson*networkMTU (Conference network packet size)
Lets you specify the underlying network packet size. If you have a network that is composed entirely of FDDI rings, set this value to the FDDI MTU of 4352 (see the output of netstat -i for appropriate MTU values). For ethernet MTU=1500, for ATM network MTU= 9188

InPerson*multicastTTL (Conference network range)
This resource affects how widely distributed the multicast packets will be through the network. It is specified in hops; maximum number of IP multicast routers between any two participants in a conference. Default value is 10. Range is 1 (meaning local net only) to 63. Audio input and output sampling rates are automatically set to the sampling rate used by the audio compression scheme. The default scheme uses a 16kHz rate.

Files

/usr/sbin/inperson
/usr/lib/X11/apps-default/InPerson
$HOME/.desktop-'hostname'/InPerson
$HOME/.InPerson.aliases

Performance tests

The initial tests were performed on two SGI Indy workstations with GIA 100 ATM

adapters. Each workstation had 2 interfaces : ethernet and ATM. We have measured the time required to transfer two images (imagel.rgb = 305.173 B; image2.rgb = 1.037.030 B) between workstations using Shared White Board and Shelf. We have also measured performance of Video Tool and Audio Tool.

- **Shared White Board**

	ATM	ethernet	load time
imagel.rgb	25 sec	23 sec	14 sec
image2.rgb	70 sec	60 sec	40 sec

- **Video Tool** Displaying a full size 320x240 pixel image at 20 fps requires about 2500Kbps of bandwidth. Video quality is very good.

window	ATM	ethernet
max 320x240	25 sec	15 sec
med 208x156	8 sec	6 sec
min 160X120	4 sec	4 sec

  You can reduce the amount of video data being sent by: freezing the video, lowering the video frame rate or using a smaller video size.

- **Audio Tool** The performance of audio is much better when we are using ATM communication between videoconference participants. The sampling rate can be changed from 8 to 48kHz (default 16kHz). Silence and echo suppresion is possible. Mute function is available.

- **Primary interface problem** We encountered problems with InPerson software on 2 SGI Indy workstations with GIA100 and an ASX100. The ATM

network works correctly(TCP/IP , NFS ...). The InPerson through Ethernet works fine. But if you try to call the other Indy through its atm-name, the destination machine never answers the call. At the same time, the caller sees himself in 2 windows (caller window and called window). This problem seems to be known by people who demonstrated SGI applications on ATM. Since inperson uses a addressing scheme @, it is necessary to have the hostname associated with the ATM interface's IP address. Because the installation instructions suggest that $hostname-atm is to be used for the ATM interface, this causes trouble (the instructions at the end of the Fore installation script). Therefore, with Inperson, after you call the remote end, you may encounter the following problems:

- The remote end stays ringing
- The local Inperson gets 2 pictures of itself.
- There might be an error from the whiteboard application.

To fix this, do the following:

- Choose yourself a hostname.
- Edit this in /etc/sys_id
- Edit this in /etc/config/netif.options: The lines describing the ATM interface (fa0) should say $hostname instead of $hostname-atm ! The lines describing the ethernet interface (ec0) should say $hostname-eth
- Reboot the system (or netstop/netstart)

To get Inperson to use the maximum bandwith, use the control selection to set the bandwith and frame rate to the maximum level. Select large screen. Use the Indycam control from Inperson for the best picture. Use SAVE to store your setting. Some additional aspects to consider include: If you use another application with an audio capability, such as movieplayer, your audio setting of Inperson set, a wrong sampling value and that produces strange sounds. Use audiotool to set it back or adapt both ends to the setting of movieplayer.

- **Calling people** If a person is not running InPerson, you will not be able to call him or her.
- **Control panels**
  - audio control panel - defines sampling rate, mute on/off, input: microphone, line, digital
  - video control panel - defines quality of colors, source: IndyCam or Analog Source, freeze on/off, live video input
  - call control panel - defines size of video windows, number of frames per second, video bandwidth, local view on/off
  - phone control panel - defines behavior of the phone
- **SHELF** - unable to run applications shared with participants at this time.

2.3.3 ProShare Video System - MS Windows-based desktop videoconferencing system

Producer / author

Intel Corp.
2200 Mission College Blvd.
Santa Clara, CA 95052
Phone: 800-538-3373
http://www.intel.com/

Information source

Network Computing, July 1, 1994
ProShare Personal Conferencing Video System, User's Guide
Intel WWW http://www.intel.com/comm-net/proshare/index.html

Description

The Intel ProShare Video System lets you use your computer for video conferences

with another ProShare Video System User. You can also share an application with the person you called. You can connect in two ways:

- ISDN digital phone lines
- LAN (TCP/IP, Novell)

ProShare is started by double-clicking the ProShare Video icon in the ProShare Video program group. ProShare window contains the Handset and two video windows (remote and local) displayed as one unit. You can separate them into 3 windows ("Split"/"Combine" button). "Info" shows the ISDN or LAN information. "Dial" changes to "hang up" during a call. "Dial list" shows the names you can call. "Edit" opens dial list set up. "Help" tells you about each button or feature.

Requirements for Intel ProShare Video System 150

- PC with Intel486(tm) 33 MHz CPU minimum. IntelDX2(tm) 66 MHz processor or Pentium(tm) processor recommended
- Windows 3.1 or 3.11
- 8 MB RAM minimum, 16 MB RAM recommended, plus 16 MB hard disk space (minimum)
- VGA display with 256 colors or higher (no feature connector required)
- Network interface card
- 1 full-length ISA slot
- Supported protocol stacks, at least one of:
  IPX: Novell VIPX, version 1.11, 1.17, 1.18
  TCP/IP: FTP PC/TCP, version 2.31
  FTP OnNet, version 1.1
  Novell LAN WorkPlace for DOS, version 4.12
  NetBIOS:Microsoft Windows for Workgroups, version 3.11
- LANDesk Personal Conferencing Manager software installed on your LAN

Technical specification for Intel ProShare Video System 150

- ProShare Video Conferencing software
- ProShare Software, Premier Edition
- Application sharing
- Shared notebook
- One full-length ISA card
- Video capture (Composite and S-Video inputs) and audio subsystem (16-bit wave)
- Full-duplex video and audio conferencing
- Half-duplex speaker phone support with optional speakers
- Intel Indeo (http://www.intel.com/IAL/indeo/indeo.html) video technology : regular quality (200 Kb total conference); high quality, available only when using on LAN/WAN (450 Kb total conference)6-bit wave audio
- Color CCD camera with NTSC output
- Combined headset/microphone unit
- Dual microphone support
- Jacks for headset, microphone, line in and line out
- Standard NTSC composite video input
- 160 x 120, 320 x 240, or icon video window size support
- Simultaneous local and remote video views
- Up to 640 x 480 high-resolution video snapshot capability
- Supports all VGA and SVGA resolutions and color modes

- LAN physical layer independent: Ethernet; Token Ring; FDDI; T-1, Frame Relay
- LAN protocols: IPX, TCP/IP, NetBIOS
- One-year limited warranty on ProShare software, camera, and headset
- Three-year limited warranty on adapter board

Requirements for Intel ProShare Video System 200

- PC with Intel486(tm) 33 MHz CPU minimum. IntelDX2(tm) 66 MHz or Pentium(tm) processor recommended
- Windows 3.1 or 3.11
- 8 MB RAM minimum, 16 MB RAM recommended, plus 17 MB hard disk space (minimum)
- VGA display with 256 colors or higher (no feature connector required)
- 2 full-length ISA slots
- For ISDN NT-1: adapter and ISDN telephone service from local phone company
- For LAN/WAN: Network interface card and supported protocol stacks.
- LANDesk Personal Conferencing Manager software installed on LAN

Technical specification for Intel ProShare Video System 200

- ProShare Video Conferencing software
- ProShare Software, Premier Edition: application sharing and shared notebook
- Two full-length ISA cards
- Video capture (Composite and S-Video inputs)

- ISDN interface and audio subsystem (16-bit wave)
- Full-duplex video and audio conferencing
- Half-duplex speaker phone support with optional speakers
- Intel Indeo video technology: regular quality (200 Kb total conference); high quality, available only when using on LAN/WAN (450 Kb total conference)
- 16-bit wave audio
- Color CCD camera with NTSC output
- Combined headset/microphone unit
- Dual microphone support
- Jacks for headset, microphone, line in and line out
- Standard NTSC composite video input
- Supported switches include: AT&T 5ESS (5E6 through 5E9, including NI-1; Northern Telecom DMS-100 (BCS-33 through BCS-36 including NI-1); Siemens EWSD (NI-1)
- PBX switch connectivity: AT&T Definity G3I, G3R; Northern Telecom Meredian-1; Teleos 20 slot; Siemens; ALCATEL; NEC
- 160 x 120, 320 x 240, or icon video window size support
- Simultaneous local and remote video views
- Up to 640 x 480 high-resolution video snapshot capability
- Supports all VGA and SVGA resolutions and color modes
- LAN physical layer independent: Ethernet; Token Ring; FDDI; T-1, Frame Relay

- LAN protocols: IPX, TCP/IP, NetBIOS
- H.320 option available in early 1995
- One-year limited warranty on ProShare software, camera, and headset
- Three-year limited warranty on adapter board

Basic functionality

- **audio :** YES (proprietary)
- **video :** YES
- **multipoint:** NO
- **shared notebook:** YES
- **shared application:** YES
- **snapshot:** YES
- **dial list:** YES

Pricelist July 1994

Price per seat	$2499.00
This includes: Indeo Video Capture board, CCD Camera, headset (microphone and earphone)	
ProShare Video System 200	$1,999
w/ local or long dist.ISDN	$1,499
w/ local and long dist.ISDN	$999
ProShare Video System 150	$1,499
ProShare ISDN Upgrade Kit	$499
ProShare Premier Edition Software	$299
Accessories for ProShare Video	

Coherent CallPort* Speaker	$399
Tone Commander NT-1	$289

Results of tests

We tested ProShare Video System version 1.8 on Compaq Deskpro XL 566 over ISDN lines.

Compaq Deskpro XL 566 configuration:

- Processor: Pentium at 66MHz
- Memory: 16 MB RAM
- A:1.44 MB, C:529 MB, D:CD-ROM drive
- Video Resolution: 800x600, 8 bit
- Architecture: Extended ISA

Shared notebook

- lets you copy a file from your computer into the notebook and review it with the person you are talking to
- you can share the same application
- you can take a shapshot of a window or a part of a window
- you can embed information from another application (Paintbrush)
- you can use several pages in the notebook
- you can type text, draw lines, rectangles, squares, ellipses and circles, choose colors

Sharing an application

- both conference participants can see the same applications and update document together ("Share document" button)

Adjusting the video image

- saturation - intensity of colors
- contrast - lightness/darkness
- brightness - allow light into the image
- tint - affects the shades of color (deep or pale)

Control panels

- "Remote window" shows the other person. It contains "remote tool panel" (volume, handset into view, speakers/headset)
- "Local window" shows your image. It contains "local tool panel" (resize, snapshot, camera control, zoom in/out, audio mute, video mute)
- "Options" (general, video, audio, user info on/off, dial list)

Audio

- You can connect external speakers

ProShare Video System 200 H.320 Interoperability Chart

The following is a list of systems that have been tested by Intel with the ProShare Video System 200 release 1.8Ha

Vendor	Model	Version	Speed
Alcatel	S02		112k/128k
AT&T	MCU	3.0	112k/128k
AT&T	Vistium 1200	1.03	112k/128k
AT&T	Vistium 1300	1.02	112k/128k

BT	BT5000	3.11	112k
BT	VC2300	E2.1	112k
BT	VC7000	J4	112k
Chips at Work	2at1 Desk	2.02	112k/128k
CLI	Eclipse 8100	1.53	112k
CLI	Eclipse 8250	2.0	112k
CLI	MCU		112k/128k
CLI	Rembrandt 9100	9.23	112k
GPT	261		112k/128k
GPT	300	3.52	112k/128k
GPT	500	3.52	112k/128k
GPT	Focus	PC Beta	112k/128k
GPT	Focus Arena MCU	2.1	112k/128k
Mentec	VS1000		112k/128k
NEC	TC5000EX	1.41	112k/128k
PictureTel	M8000	2.1	112k/128k
PictureTel	PCS Live 100	1.1	112k/128k
PictureTel	PCS Live 50	1.0	112k/128k
PictureTel	System 1000		112k/128k
PictureTel	System 4000E	4.0,4.1,4.2	112k/128k
PictureTel	System 4000Ex	5.1	112k/128k
Sony	PCS2000	2.0, 2.1	112k/128k
Tandberg	Compact Vision	A1	112k/128k
Video Server	MCU 2000		112k/128k
Vivo	Vivo320	1.0	112k/128k
VTEL	DeskMax	1.2, 2.0	112k/128k
VTEL	MCU	1.1	112k/128k
VTEL	MediaMax	3.01	112k/128k
VTEL	Smax 2.0		112k/128k

2.4 Videoconferencing Standards

Today's videoconferencing systems are proprietary, requiring identical technology at each end of the conference. While some multivendor standards exist , standards remain an open question. One feature to look for in a conferencing product is support for the H.320 interoperability standards. This will enable the desktop system to work with H.320-compliant room systems and desktop systems from the same or different vendors.

Here is the list of existing videoconferencing standards:

- **F.700** - Audiographic, Videotelephony and Videoconference service standards (CCITT, 1993)
  - F.711 - Audiographic Conference Teleservice for ISDN
  - F.720 - Videotelephony Services General
  - F.721 - Videotelephony Teleservices for ISDN
  - F.722 - Videotelephony Services General
  - F.730 - Videoconference Services General
  - F.732 - Broadband Videoconference Services
  - F.740 - Audiovisual Interactive Services
- **G.700** - CCITT, 1992
  - G.711 - Pulse Code Modulation (PCM) of voice frequencies (64 Kbps 8KHz 8-bit PCM audio encoding)
  - G.721 - 32 Kbps Adaptive Differential Pulse Code Modulation (ADPCM) for audio encoding
  - G.722 - 7 KHz audio encoding within 64 Kbps
  - G.725 - System Aspect of the use of 7 KHz audio codec within 64 Kbps
  - G.728 - Audio encoding

- **H.231** - This standard covers Multipoint Control Units and defines how three or more H.320-compatible videoconferencing systems link together in a single conference.

- **H.233** - This standard specifies the data-encryption methodologies supported under H.320.

- **H.241** - Signalling for conferencing

- **H.243** - This standard covers Multipoint Control Units and defines the MCU protocol standard

- **H.261** - The compression component of H.320. It specifies a range of intraframe and interframe compression algorithms that can work with Px64 digital channels (64 Kbps to 2.048 Mbps)

- **H.320** - The dominant videoconferencing standard developed by the ITU-T (International Telecommunications Union - Telecommunications Standards Section). It is a standard for describing videoconferencing terminals, but the term H.320 has come to represent a whole suite of specifications for enabling compliant vidoeconferencing sessions. It was originally adopted for room-based videoconferencing and for digital lines such as ISDN. H.320 includes: H.221 - framing protocol

- **H.KEY** - Standardizes the electronic management of encryption keys

- **T.120** - Standardizes the electronic management of encryption standards in development. It will cover document sharing protocols. Once T.120 is adopted, compliant whiteboard applications will be able to talk to one another. One usually associates desktop videoconferencing with talking heads and smiling faces. T.120 suite of standards is emerging as the main mechanism that will enable users to work together on documents such as text files, spreadsheets and graphic images. T.120 comprises three components

  - T.123 - Network protocols defined in T.123 allow communication over a wide variety of standard networks, including LANs, ISDN and POTS.
  - T.122 and T.125 - Multipoint Communication Services provides a connection-oriented service that is independent of the T.123 transport stacks operating below it.
  - T.124 - Generic Conference Control provides conferencing capabilities by outlining services to set up and manage a multipoint meeting, addresses conference security (passcode protection), provides general conference administration.
  - T.126 - Allows users to view and annotate images, share applications
  - T.127 - Gives users the ability to initiate simultaneous multipoint file transfer.

- **CIF** - Common Intermediate Format. The optional high-resolution display format at 352 x 288 -pixel resolution

- **QCIF** - Quarter CIF. The minimum display format of 176 x 144 pixel resolution.

2.5 MOO Object Oriented MUD's

A MOO "...is a network-accessible, multi-user, programmable, interactive system well-suited to the construction of text-based adventure games, conferencing systems, and other collaborative software. Its most common use, however, is as a multi-participant, low-bandwidth virtual reality..." (excerpted from the "LambdaMOO Programmer's Manual", version 1.7.6, written by Pavel Curtis). MOO's stand for Object Oriented MUD's where MUD stands for Multi-User Dungeons or Multi-User Dimensions.These are "virtual-reality" or more precisely "virtual-community" systems. MOO's are a modern object oriented implementation of the older MUD's and are developed at XEROX PARC in Palo Alto. The goal is to set up a computer environment which resembles more or less faithfully the real world. Rather perversely, they use a fundamental spatial model but are entirely (but elegantly) text based.

MOOs are composed of three types of elements: People, places, and things. Because one of the goals of a MOO is to resemble (within the limitations of the medium) reality, MOOs have many of the things that one would see in everyday life: cars and houses, people and refrigerators, pets and so forth. The people who inhabit MOOs attempt to add as much detail to the MOO as possible. This means adding details as simple as making a character able to smile or as complex as establishing a democratic system by which the MOO is governed (such as the one that exists at LambdaMOO). This is a list of MOOs that have WWW gateways. There's a web page (http://www.maths.tcd.ie/pub/mud/moo-www/directory.html) dedicated to the merging of MOO and WWW technology.

- BayMOO (http://baymoo.sfsu.edu:4242/)
- JHM (http://jhm.ccs.neu.edu:7043)
- MirrorMOO (http://mirror.ccs.neu.edu:8080/obj/mirrormoo)
- schMOOze Uni (http://arthur.rutgers.edu:8888/)
- Sprawl (http://sensemedia.net/sprawl)
- Meadow (http://meadow.iglou.com:1111/)
- AstroVR (http://astrovr.ipac.caltech.edu:8888/)
- MiamiMOO (http://moo.cas.muohio.edu/~moo/)
- MOOtiny (http://spsyc.nott.ac.uk:8888/)
- GopherMOO (http://monopoly.cs.umn.edu/~jpr/gophermoo)
- BioMOO (http://bioinfo.weizmann.ac.il:8888)

The "MOOs with WWW gateways list" is maintained by Kenneth R. Fox (http://www.ccs.neu.edu/home/) and can be found on his MOO-Cows FAQ (http://www.ccs.neu.edu/home/fox/moo/).

2.6 MBONE - Multicast Backbone

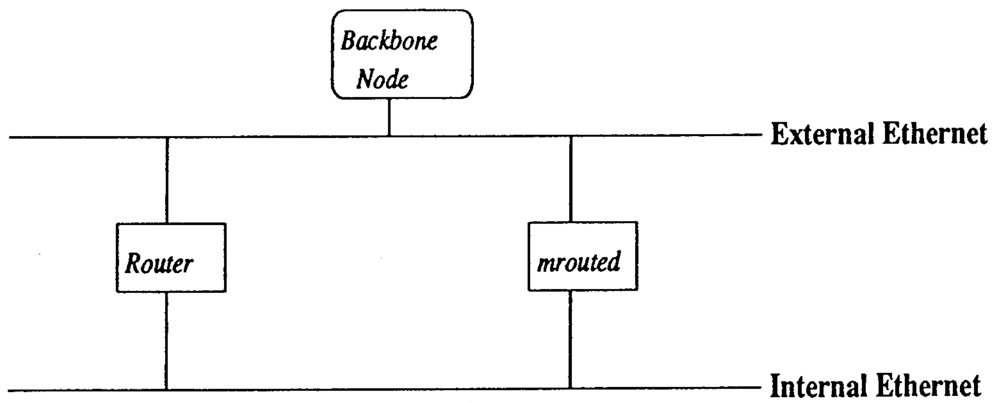
Introduction

Short for "Multicast Backbone" , MBONE is a virtual network that has been in existence since early 1992. It is a network of hosts connected to the Internet communicating using a technique called IP multicast and is used to develop protocols and applications. Multicast provides one-to-many and many-to-many network delivery services for applications such as videoconferencing and audio where several hosts need to communicate simultaneously.

IP-Multicast is the class-D addressing scheme in the Internet Protocol (IP). IP Multicast-based routing facilitates distributed applications to achieve time-critical and "real-time" communication over wide area IP networks through a lightweight highly threaded model of communication. Video, audio, and a shared drawing whiteboard are the principal applications, provided by software packages called nv (network video), vat (visual audio tool), and wb (whiteboard). The MBONE software is available in http://mice.infn.it/software.html.

Technical facilities and equipment required

Each network-provider participant in MBONE provides one or more IP multicast routers to connect with tunnels to other participants and to customers. The multicast routers are typically separate from a network's production routers since most production routers don't yet support IP multicast. Most sites use workstations running the mrouted program. It is best if workstations can be dedicated to the multicast routing function to avoid interference from other activities. Since most MBONE nodes other than endpoints will have at least three tunnels, and each tunnel carries a separate (unicast) copy of each packet, it is also useful, though not required, to have multiple network interfaces on the workstation so it can be installed parallel to the unicast router for those sites with configurations like this:



End-user sites may participate with as little as one workstation that runs the packet audio and video software and has a tunnel to a network-provider node. The most convenient platform configuration supporting the mrouted program is a Sun SPARCstation running SunOS 4.1.1,2,3 with a network interfaces ie, leand lo
The IP multicast software is available by anonymous FTP from the vmtp-ip directory on host "gregorio.stanford.edu".
Binaries and patches for SunOS 4.1,2,3 : ipmulti-sunos41x.tar.z
Kernel sources are not needed to add the multicast support. Included in the distributions are files (sources or binaries, depending upon the system) to modify the kernel to support IP multicast, including the mrouted program and special multicast versions of ping and netstat.

Hardware requirements

- Most of the applications have been ported to the Sun SPARCstation.
- No additional hardware is required to receive audio and video on the systems that have audio built in. The rest is done in software.
- To send audio requires a microphone; to send video requires a camera and a video capture device.
- For the camera, any camcorder with a video output can be used. The wide-angle range is most important for monitor-top mounting. There is also a small

(about 2x2x5 inches) monochrome CCD camera suitable for desktop video conference applications available for around $200 from Stanley Howard Associates, Thousand Oaks, CA, phone 805-492-4842. It is sufficient for 320x240 resolution software video algorithms. There is also a color model and an infrared one for low light, with an IR LED for illumination.

- For the "nv" (network video) program, an 8-bit visual is recommended to see the full image resolution, but nv also implements dithering of the image for display on 1-bit visuals (monochrome displays). Shared memory will be used if present for reduced processor load, but display to remote X servers is also possible.On the SPARCstation,the VideoPix card is required to originate video.
- The "ivs" program has the following system requirements: SUN SPARCstation or SGI Indigo, video grabber (VideoPix Card for SPARCstations), video camera, X-Windows with Motif or Tk toolkit.

Software requirements

The audio and video applications can be run point-to-point between two hosts using normal unicast addresses and routing. To conference with multiple hosts, each host must run the operating system kernel with IP multicast support. IP multicast invokes Ethernet multicast to reach multiple hosts on the same subnet; to link multiple local subnets or to connect to the MBONE, a multicast router (as described above) is needed.

Free IP multicast software can be picked up and added to SunOS 4.1.x (as is described above). The IP multicast kernel software releases for SunOS include a patch for the module in_pcb.c. This patch allows demultiplexing of separate multicast addresses so that multiple copies of vat can be run for different conferences at the same time.

To run a SunOS 4.1.x kernel, the kernel audio buffer size variable should be patched from the standard value of 1024 to 160(decimal) to match the audio packet size for

minimum delay. The IP multicast software release includes patched versions of the audio driver modules, but if for some reason they cannot be used, adb can be used to patch the kernel as shown below. These instructions are for SunOS 4.1.1 and 4.1.2; the variable name should be changed to amd_bsize for 4.1.3.
adb -k -w /vmunix /dev/mem
audio_79C30_bsize/W 0t160 (to patch the running kernel)
audio_79C30_bsize?W 0t160 (to patch kernel file on disk)

If the buffer size is incorrect, there will be a bad breakup of the audio when the sound from two sites gets mixed for playback.

SOFTWARE FOR AUDIO APPLICATIONS

- The most popular application on the MBONE is the LBL audio tool "vat". A beta release of vat is available by anonymous FTP from ftp.ee.lbl.gov in the directory conferencing/vat where the following tar files can be found: sun-vat.dyn.tar.Z (dynamic libraries), sun-vat.tar.Z (static libraries).

  Included in the vat tar files are binaries and a manual entry. The source will be released soon. Either SPARC version will run SunOS 4.1.x.

- A beta release of both binary and source for the audio tool NEVOT is available by anonymous FTP from gaia.cs.umass.edu in the pub/hgschulz/nevot directory (the filename may change from version to version). NEVOT runs on the SPARCstation and supports both the vat protocol and RTP protocol.

SOFTWARE REQUIRED TO RECEIVE VIDEO

- The "nv" (network video) program is available from parcftp.xerox.com in the file pub/net-research/nv.tar.Z.

- Also available from INRIA is the IVS program. It uses a more sophisticated compression algorithm, a software implementation of the H.261 standard. It produces a lower data rate, but because of the processing demands, the frame

rate is much lower and the delay higher. Binaries and sources are available for anonymous ftp from avahi.inria.fr in file pub/videoconference/ivs.tar.Z or ivs binary sparc.tar.Z.

Teleconference events

Many of the audio and video transmissions over the MBONE are advertised in "sd", the session directory tool developed at LBL. Session creators specify all the address parameters necessary to join the session, then sd multicasts the advertisement to be picked up by anyone else running sd. The audio and video programs can be invoked with the right parameters by clicking a button in sd. From ftp.ee.lbl.gov get the file sd.tar.Z.

Analysis of basic functionality

- SESSION DIRECTORY PACKAGE (sd) Session availability is dynamically announced using this tool. It displays active multicast groups. The sd tool also launches multicast applications and automatically selects unused addresses for any new groups. Clicking on session name gives information about the session such as time and date of transmission of the session. Double clicking on the session name starts up the appropriate tools (eg. vat, nv) for the desired session.

- NETWORK VIDEO PACKAGE (nv) This is a videoconferencing tool. For a default bandwidth of 128kbps, typical frame rates of 3-5 frames per second can be transmitted or received.

- VISUAL AUDIO TOOL (vat) This tool allows host to host or multihost audio conferencing and can use a variety of data compression formats. The vat utility produces a conference hosts window which shows all hosts currently participating in the conference. The name of the host currently transmitting is displayed in a box. This box is video-reversed. It is not necessary to speak in order to participate in a conference, but the normal etiquette is to wait until the speaker has finished and has opened questions to the floor or to the net, before

speaking. Using vat requires a certain amount of prudence to avoid accidental transmissions during conference sessions.

- WHITE BOARD UTILITY (wb) This utility can be used as a shared white board drawing surface and it can be used to export and view postscript files. Speakers can make their slides available as postscript files during a conference session. The camera can be directed at the speaker while the slides can be viewed via wb.
- AUDIO AND VIDEOCONFERENCING PACKAGE (ivs) This package is used to participate in MICE(Multimedia Integrated Conferencing for Europe) seminars.
- IMAGE MULTICASTER CLIENT (imm) This is a high resolution, low bandwidth image server providing live images of the earth from various geostationary satellites at half-hour intervals in either visible or infrared spectra.
- AUDIO TOOL (nevot) This is a network voice terminal providing multiple party conferences with a choice of transport protocols.
- MMCC This is a session orchestration tool and multimedia conference control program.

Data rate produced by the audio and video applications

NPS runs MBONE tools on workstations connected via Ethernet(10Mbps).Off-campus links are via T1 lines (1.5Mbps). The audio coding provided by the built-in audio hardware on most systems produces 64Kb/s PCM audio,which consumes 68-78 Kb/s on the network with packet overhead. The audio applications implement software compression for reduced data rates (36 Kb/s ADPCM, 17 Kb/s GSM, and 9 Kb/s LPC including overhead.

For the slow-frame-rate video prevalent on the MBONE, all the compression, decompression and displays are all done in software. The data rate is typically 25-128

Kb/s with the maximum established by a bandwidth limit slider. Higher data rates may be used with a small TTL to keep the traffic within the local area. Support for hardware compression boards is in development.

2.7 Web Collaboration Examples

There is a wide variety of information available on collaboration on the World Wide Web and many resources for further exploration. There are also several good resources for learning about current work on collaboration, issues, and directions.

- NCSA's Web Collaboration Projects -
  http://union.ncsa.uiuc.edu/HyperNews/get/www/collaboration.html
- Daniel LaLiberte's "A Protocol for Scalable Group and Public Annotations" -
  http://union.ncsa.uiuc.edu/~liberte/www/scalable-annotations.html
- Collaborative Software Clearinghouse at University of Hawaii -
  http://www.ics.hawaii.edu/~csrc/
- Interactivity Discussion on WWW-Talk -
  http://www.geom.umn.edu/hypernews/get/interactive/index.html

These are implemented WWW collaboration systems whose sophistication and domains span an interesting range.

Collaborative Authoring

- Authorable Story Base - http://discus.ise.vt.edu/cgi-bin/wwwproj/story
- DACLOD, a distributedly administered centrally stored database of hyperlinks - http://schiller.wustl.edu/DACLOD/daclod?id=00023.dcl

Structured Discussions

- Web Interactive Talk -
  http://www.w3.org/hypertext/WWW/Discussion
  http://www.w3.org/hypertext/WWW/WIT/User/Overview.html

- The Vice President's Electronic Open Meeting - http://www.npr.gov/OpenMeet/openmeet.html

Threaded Discussions

- HyperNews, WWW meets USENET - http://union.ncsa.uiuc.edu/HyperNews/get/hypernews.html
- Time Warner's Bulletin Boards - http://www.timeinc.com/pathfinder/bbs-home.html
- Webnotes Conferencing System - http://webnotes.ostech.com/
- WebNotes - http://www.ostech.com/
- The MecklerWeb Discussion Thread - http://www.netgen.com/cgi/mweb
- Spam Home Page - http://sp1.berkeley.edu/findthespam.html

Annotation Servers

- Cornell Annotation System - http://dri.cornell.edu/pub/davis/annotation.html
- NCSA Hypernews - http://union.ncsa.uiuc.edu/HyperNews/get/hypernews.html
- Brio System - http://www-pcd.stanford.edu/ANNOT_DOC/
- Public Annotation Systems - http://playground.sun.com:80/~gramlich/1994/annote/

Brokerage Servers

- MORE, a Multimedia Oriented Repository Environment - http://rbse.jsc.nasa.gov:81/DEMO/
- WSRS - http://ulinf0.unil.ch:8000/wsrs

Interactive Chat Systems

- WebChat - http://www.irsociety.com/webchat.html
- IRC to Web gateway - http://www.infosystems.com/cgi-bin/www2irc
- Peach Web Hyperchat - http://www.peachweb.com/chat/chat.html
- IQUEST Conference Rooms - http://www.iquest.net/cgi-bin/cr/
- Cybersight Real-Time Chat - http://cybersight.com/cgi-bin/cs/ch/chat
- Web Forum - http://issco-www.unige.ch/WebForum/
- WWW ChatServer - http://www-bprc.mps.ohio-state.edu/Chat/
- TSW Commons Caucus An Interactive Forum -
http://starbase.ingress.com/tsw/mail/index.html

3 Project Information Server

3.1 Objectives

- Installation and configuration of the Web server to support delivery of documents and data related to the project
- Set up the Web interface to support NYNET demonstartions as simulation on demand (infrastructure for attractive and automatic delivery of demonstrations)
- Caching of frequently accessed information to improve performance of Mosaic client/server software
- Installation of Web-Oracle gateway

3.2 Server Installation

The NCSA http server (release 1.3) has been installed on a SGI Challenge in NPAC. The server [Appendix D, Figure 1] can be accessed via the following URL : **http://kopernik.npac.syr.edu:1200/index.html.** It was designed to deliver all documents and data related to the project including:

- General information about the project (Technical Proposal and Statement of Work)
- Deliverables and Progress Reports
- Description of each task (objectives, status of work)
- Description of Technologies (collaboratory, caching, high-speed networking, compression, image processing)
- Demonstration page

We have installed the second server on an IBM Power Station. It is used as a gateway to the Oracle 7.0 database (http://kayak.npac.syr.edu:1200/).

The simulation on demand front-end installed on the server is based on the http client/server and X client/server models. The following demonstration programs are available:

- Chemistry Transport in the Atmosphere
- Electomagnetic Scattering Simulation
- Radar Cross Section Simulation
- Stock Option Pricing Model

3.3 Caching Frequently Accessed Documents

Problems

- The poor performance suffering of the current Mosaic is mostly due to the networking bandwidth/traffic problem, not the performance in querying/locating information
- NCSA Mosaic is quite slow in formatting and displaying pages with large inline images
- Mosaic downloads the whole image or movie before starting the external viewer (e.g. xv, mpeg-play)
- Using Mosaic and following the hyperlinks takes a lot of time

Objectives

- Data replication is a known solution with "pre-fetching", "caching" and "cache coherence" as issues
- **Mining** - retrieves WWW resources relevant to selected subject (multidocument, automated - done by Web robots)

- **Caching** - retrieves pages from the Web, scans them for references, and copies pages to a local cache after rewriting the references to the pointers to the local cache (It is done by proxy servers)

- Server should fetch data from Internet and store on local disks - this allows one to deliver information at full speed of an optimized community network without limitation of lower speed global networks.

Existing solutions - mining

- **WEBWALKER** from Argone National Laboratory
  (author:**Bob Olson** - olson@mcs.anl.gov)
  Description: System provides a framework for a flexible Web walking based on 'w3get' by Brooks Cutter.

  - perl5 script
  - host-distance restrictions
  - round robin scheduling of URL retrievals (to avoid swamping any individual server)
  - fast full-text searches of Web pages

  References and source of information:
  http://www.mcs.anl.gov/home/olson
  http://www_mirror.mcs.anl.gov/
  http://www_mirror.mcs.anl.gov/cgi-bin/aglimpse/01.

  Plans for future: replacement of URLs (Uniform Resource Locators which hard wire the Internet locations) by URN scheme (Uniform Resource Names - the generalized version of URLs).

- **W3GET** - points it at a http URL and recursively retrieves href's and img src's starting from that page
  Author: **Brooks Cutter** (bcutter@paradyne.com)

Description: This is a shell (sh) archive; requires at least perl ver 4.0.36
References and source of information:
http://www.stuff.com/~bcutter/home
http://www.stuff.com/cgi-bin/bbcurn?user=bcutter&program=w3get

- **WWW WORM** - builds index lists of Internet assets for datamining purposes. The index is stored in the standard UNIX directory tree structure.
  Author: **Oliver Mc Bryan**
  References and source of information:
  http://www.cs.colorado.edu/home/mcbryan/WWW.html
  http://web.nexor.co.uk/mak/doc/robots/active.html
  http://web.nexor.co.uk/mak/doc/robots/robots.html
  The last reference contains the list of robots and automated Web-travelling tools. See also "Caching and Mining" list in chapter 7.

Proxy servers - caching

Use of cache techniques that are already available can alleviate the load on the network. In its current form, each WWW reference (URL) specifies or implies a reference to one particular host on the Internet. This means that without some kind of additional machinery, every WWW reference, no matter where it is from and no matter how often it is made, will make a network call to that specific site (or several calls, if there are embedded images), leading to unnecessarily high use of network links (particularly international ones) and excessive load on popular servers. The cache techniques can be applied with the software available today. Use of a proxy server is a recognized technique and most modern WWW clients ("browsers") support it. Web client software can be configured to use the Proxy for making its WWW accesses. The Proxy makes any necessary document retrievals on behalf of the client and returns the data to the user.

There are two main reasons for operating a proxy:

1. For crossing a network firewall

2. For maintaining a document cache

When the user requests a particular URL via the proxy, the proxy looks to see whether a (recent) copy of that URL is available from its cache, and if so, returns it directly. If not, it requests the document from the indicated server and passes the data back to the client, at the same time keeping a copy in its cache[Appendix D, Figure 2].

The "cache proxy" (or "proxy cache") server is, at one and the same time, a "proxy" *(it accepts requests from clients and carries them out on the clients' behalf) and a* "cache" *(it keeps a copy of the documents that it retrieves and fulfils subsequent requests from that copy where appropriate).*

Many Web client packages can be configured with a list of domains from which they will retrieve data directly, without using the proxy, and the local domain(s) should usually be put into this list.

Clients should be configured to fetch local documents directly, while fetching all other documents via the local cache proxy. Techniques are needed for ensuring that the Proxy does not issue out-of-date documents to clients.

Examples of "free" Proxy Cache packages include the following:

- Lagoon - http://www.win.tue.nl/lagoon/
- CERN HTTPd Web server - http://www.w3.org/hypertext/WWW/Daemon/User/
- Harvest Object Cache - http://excalibur.usc.edu/
- Ichthus Cache - http://www.gh.cs.usyd.edu.au/Cache/
- X Mosaic 2.4 Cache - http://www.gh.cs.usyd.edu.au/Cache/help-on-cache-2.4.1.html

Harvest - the object caching tool constructed on University of Southern California and University of Colorado at Boulder. Harvest consists of:
- Gatherer (collects indexing information)

- Broker (provides indexed query interface)
- Index/Search (WAIS, Glimps interfaces)
- Object cache (HTTP,FTP,Gopher)

Netscape Proxy server

The Netscape Proxy Server provides access to the Internet and World Wide Web through a firewall machine. It also povides the following capabilities:

- Safe passage through the firewall, including proxying secure protocols (SSL, HTTPS, NNTPS)
- Caching of documents to a local file system
- Access control to remote servers and protocols based on URLs, client hostnames, and user names
- High-level logging of client transactions

Forms are usually submitted with the POST method and documents resulting from POST are never cached, in any circumstance. Only GET documents may be cached and only if they have a Last-modified and/or Expires header (with non-zero time to live). Script outputs do not usually have these headers. The Proxy is not incorporated into the Communications or Commerce Servers. First and most importantly, most of the time, proxies and HTTP servers support different groups of users. Proxies allow internal users to go out on the Internet while HTTP servers also allow external users in from the Internet. Often they run on different machines and have different security levels and network setups. It is also easier to configure these obviously very different tasks when they are separated into different products.

Implementation, tests and experiences

- We downloaded perl5 and installed it on a Sun platform
  ftp://ftp.uu.net/systems/gnu/perl5.000.tar.gz-split/part[01-04]

- We installed the available version of WEBWALKER. Unfortunately, the software is incomplete and contains serious bugs. The Webwalker retrieves pages from the Web, scans them for references, and copies pages to a local cache after rewriting the references to the pointers to the local cache. However, the current software produces wrong local references when it finds 'nonstandard' html constructions or mistakes in html documents. Moreover, caching takes hours and about 30% of the documents are downloaded incorrectly because of problems during data transmission or with permission restrictions.

- Here are the results of caching for Kid's Web:

  - The whole Kids-Web starting from http://www.npac.syr.edu/textbook/kidsweb/index.html with maximum number of hops, max_dist= 1. The intent behind max_dist is that it is the number of hops in terms of servers, such that the starting point server is distance 0 and servers that are pointed to by pages on a server of distance D are defined to be distance D+1. Any pages referenced on a server of distance D <= max_dist are retrieved.

run-time	12.5 hours (night)
# of hosts visited	1329
# of files downloaded	8444
disk space	151 MB

    Formally, it would take 8 seconds to deliver this info over OC3 ATM link

  - Only the Biology part starting from http://www.npac.syr.edu/textbook/kidsweb/biology.html with maximum number of hops = 1

run-time	4.5 hours (day)
# of hosts visited	322
# of files downloaded	2794
(1488html, 846 gifs, 60ps, 534 rejected)	
disk space	27 MB

– Only the Biology part starting from with maximum number of hops = 2

run-time		6.5 hours (night)
# of hosts visited		794
# of files downloaded		8124
disk space		110 MB
Site Type	Hosts#	Files #
edu	353	2521
com	100	538
gov	46	373
org	27	103
net	24	120
mil	9	36
us	3	18
uk	72	422
ca	22	70
au	19	60
de	16	78
nl	14	58
ch	13	126
no	9	32
it	8	37
fr	7	27
be	6	24
at	4	23
jp	3	8
dk	2	6
si	1	5
pl	1	7

- Total information on the Internet (based on extrapolation from Kids Web Caching Experiments)
  - 4600 WWW Servers reqistered at CERN (12.01.94)
  - Total Space about 1 TB = 1500 CD ROM's
  - TEXT Space : 185 million pages (one page is about one KB; 685 times text in Encyclopedia Britannica [EB])
  - IMAGE Space: 5 million pictures (317 times images in EB)
  - MOVIE Space : 280 hours of small mpeg compressed material
  - Use of space: 20% text, 60% images, 3% movies, 17% other
  - Current increase in traffic on the WWW is 1% per day

3.4 WOW - The Web-Oracle-Web Connection

Overview

WOW is a utility that allows a user to develop CGI gateways for Web-servers with PL/SQL in an Oracle7 database. This offers a couple of benefits that are normally missing in CGI. Since WOW procedures are executed within an Oracle database, they automatically inherit the following characteristics of this fine database:

- Scalability
- Portability
- National Language Support
- Multi Threaded Servers
- Replication
- Distribution
- Administration (SNMP)

- Object encapsulation (PL/SQL packages)

Architecture[Appendix D, Figure 3]

WOW consists of 5 parts including:

- A small shell-script to set environment-variables
- An C stub called wowstub implemented as a *normal* CGI program
- A PL/SQL package called *wow*
- An optional, but strongly recommended set of PL/SQL packages called *HTP* and *HTF* . These encapsulate HTML formatting and will make migration to future HTML versions easy.
- A standalone PL/SQL compiler with CGI enhancements. The compiler is a standalone gateway that will allow you to execute PL/SQL code directly from within an HTML document.

wowstub uses *PATH_INFO* to extract the name of the procedure to execute. Additional parameters are extracted and decoded before passing them to the PL/SQL procedure. Both the *GET* and *POST* methods are supported. **HTF** and **HTP** use the standard Oracle package *DBMS_OUTPUT* to write back to **wowstub**, which finally dumps the output to *stdout*, which is what a CGI gateway basically does.

PL/SQL Compiler With CGI Extensions

The included PL/SQL compiler is an enhanced version of the **PL/SQL v2.3 alpha** standalone compiler. It is very easy to use and expects an HTML form in a document to pass the following mandatory fields:

- **PROGRAM** contains the PL/SQL code. If it is an *anonymous* PL/SQL block, it will be compiled and executed by the gateway. If it is a PL/SQL *procedure, package, or function* definition, it will be passed to the database and saved there instead. This means that the PL/SQL compiler may be used to test and debug WOW gateways!

- **ORACLE_HOME** points to your Oracle home directory.
- **TWO_TASK** is a *SQL*NET v2* descriptor.
- **TNS_ADMIN** points to the directory containing tnsnames.ora (file with SQL*Net descriptors).
- **USER** is the Oracle username.
- **PASSWORD** is the Oracle password.
- **EXD** points to a directory containing compiled PL/SQL packages (*htp* and *htf* described above are stored here).

WOW demos

Here are some additional demos:

- http://kayak.npac.syr.edu:1963/ by Gang Cheng (NPAC)
- http://kayak.npac.syr.edu:1200/ by Jiangang Guo (NPAC)
- http://dozer.us.oracle.com:8080/sdk10/wow/wow.html

General Information About Oracle 7 Installation

The Oracle 7.0 server(ORACLE7 Server Release 7.0.15.4.0, PL/SQL Release 2.0.17.1.0, CORE V2.2.10.1.0) has been installed on kayak.npac.syr.edu (128.230.3.70) IBM Power Station in NPAC. The software tools include: PL/SQL, SQL*DBA, SQL*Plus, SQL*TextRetrieval, report writers, Pro*C, Pro*Fortran, and Pro*Cobol, SQL and Oraperl.

4 NYNET Support for Information Services

4.1 Objectives

- Configuration of NYNET and NPAC resources to support the InfoMall activities
- Implementation of NYNET infrastructure at NPAC - ATM / ISDN based laboratory

4.2 NYNET

An experimental broadband communications network is being constructed in New York State under the sponsorship of NYNEX. Using fiber optics and emerging Asynchronous Transfer Mode (ATM) switching technology, the NYNET network provides a perfect testbed for the National Information Infrastructure (or Information Superhighway) and a phenomenal opportunity for business.

The National Information Infrastructure is considered a critical asset for the economic future of this country. Industry and governmental programs have made significant progress in establishing the feasibility and in developing the network technology.

ATM is an emerging broadband switching technology being adopted by the computer and communications industry and will equally support the transfer of voice, data and video. Operating at rates as high as 2.4 gigabits per second, NYNET will permit development of a broad range of applications in industries such as health care, education, and finance. Future focus will be on new applications that will transform the way people work, learn and receive social services.

NYNET links academic, government and industrial research groups throughout New York State. Universities such as Cornell, Syracuse, Polytechnic and Columbia are connected to laboratories at Brookhaven, Rome and Cold Spring Harbor and to research centers at Grumman and NYNEX[Appendix D, Figures 4,5]. Through NYNET, each of these centers will achieve enhanced access to super computing facilities, ready-made environments for collaborative research, and a testbed to develop

applications for the National Information Infrastructure. Along with the network, the NYNET Initiatives offer collaborative projects that can benefit New York State, the region, industry, and society. Through the creation of the NYNET network and the NYNET Initiatives, NYNEX acts as an economic development catalyst stimulating regional business opportunities on the emerging National Information Infrastructure.

Current projects focus on developing collaboratory technologies to support medical and educational goals (i.e., telemedicine and long-distance learning)

Applications developed within the NYNET environment will be readily transferable to industry and portable to any national network as it emerges. In fact, the potential exists to link NYNET to other nationwide testbed efforts already in progress. NYNET is a prototype of the GII - Global Information Infrastructure. The current state of NYNET connections is available on the NMF's Information Server(http://155.244.30.103:8080/), administrated by Rome Laboratory. General information about NYNET can be found on the NPAC server -
http://www.npac.syr.edu/users/hariri/general/index.html.

4.3 ATM Network in NPAC

Below is the list of the machines in NPAC which we have currently connected to NYNET:

166.101.20.11 - Sun 10, SBA-200 ATM Sbus, SunOS 4.1.3
    kepler-atm.npac.syr.edu
166.101.20.12 - Sun IPX, SBA-200 ATM Sbus, SunOS 4.1.3
    hubble-atm.npac.syr.edu
166.101.20.17 - SGI Onyx, VMA-200 ATM VMEbus IRIX 5.3
    sandman-atm.npac.syr.edu
166.101.20.14 - SGI Indigo, GIA-100 ATM, IRIX 5.3
    newton-atm.npac.syr.edu
166.101.20.16 - SGI Indy, GIA-100 ATM , IRIX 5.3
    brahe-atm.npac.syr.edu
166.101.20.18 - Sun IPX, SBA-200 ATM Sbus, SunOS 4.1.3

mickey-atm.npac.syr.edu

166.101.20.1 - ASX-200 FORE switch, 2 OC/3 sm, 4 TAXI, 4 OC/3 mm

166.101.20.2 - ASX-200 FORE switch, 4 OC/3 mm, 4 TAXI, 4 OC/3 mm

128.230.117.200/128.230.98.1 - LAX 20, 1 OC/3 mm, 8 ethernet

We bought the second FORE ASX200 switch (February 95), upgraded our old FORE ASX100 to 200 (March 95) and installed the GTE Spanet switch (March 95). We have also installed a LAX 20 which works as a gateway between our network and the ATM network installed in Fowler HS, Rome Free Academy, Whitesboro Middle School and Rome Laboratory[Appendix D, Figures 6,7]. We installed 2.3.7 release of FORE software on both ASX 200 switches and 2.3.14 release on workstations. The FORE software on Sun 10 workstations has been upgraded to 3.0.2 release. Simple Protocol for ATM Network Signaling (SPANS) cannot run on most of NYNET because NYNET is using other switches that use other signalling protocols. SPANS works just locally on our ATM cluster. Therefore, the only way to create connections at the moment is through Permanent Virtual Channels (PVCs) set up by hand by the managers of the switches. This manual configuration stuff is a real pain! NYNEX is currently building the PVCs that will interconnect the NYNET sites. They are as follows:

Cornell <-> Columbia : 0/35

Rome <-> Cornell : 0/33, 0/151

Rome <-> Columbia : 0/36, 0/60, 0/70, 0/71

NPAC <-> Columbia : 0/40, 0/41

NPAC <-> Rome : 0/32, 0/150

NPAC <-> Cornell : 0/34, 0/250, 0/251, 0/252, 0/253

NPAC <-> NYNEX : 0/35, 0/153

All PVCs remaining Upstate are capable of bursting at peak rates up to the OC-3 access rate (~350,000 cells/sec). PVCs traversing the DS-3 Upstate-Downstate trunk are limited to 64 Kb/s < source-peak-rate <36.846 Mb/s.

NPAC <-> Columbia University

We have created PVCs between NPAC, Syracuse University and Columbia University. This is the list of the machines connected currentely at Columbia to NYNET (Franco Marconcini - franco@ctr.columbia.edu, Nikos Aneroussis - ctr-nynet@ctr.columbia.edu, Shawn B. Mishler - shawn@mail.ilt.columbia.edu):

166.101.70.10 xorn-atm.ctr.columbia.edu (CTR switch)
166.101.70.19 nova-atm.ctr.columbia.edu (host)
166.101.70.20 homer-atm.ctr.columbia.edu (host)
166.101.70.21 quasar-atm.ctr.columbia.edu (host)
166.101.70.28 comet-atm.ctr.columbia.edu (host)
166.101.70.29 meteor-atm.ctr.columbia.edu (host)
166.101.70.36 argo-atm.ctr.columbia.edu (host)
166.101.70.37 vega-atm.ctr.columbia.edu (host)
166.101.70.4 nucleus-atm.net.columbia.edu (Columbia ACis switch)
166.101.70.97 barbera-atm.ctr.columbia.edu (host)
166.101.70.98 hanna-atm.ctr.columbia.edu (host)
166.101.70.99 disney-atm.ctr.columbia.edu (host)
128.59.68.40 asteroid.ctr.columbia.edu (host running Communique!)
128.59.68.39 pulsar.ctr.columbia.edu (host running Communique!)

We have created PVC 0/40 and 0/41 connecting kepler-atm.npac.syr.edu with meteor-atm.ctr.columbia.edu, asteroid.ctr.columbia.edu and pulsar.ctr.columbia.edu.

NPAC <-> Cornell University

166.101.30.2 ASX switch
166.101.30.3 ASX switch
166.101.30.4 ASX switch
166.101.30.52 atmvla.cs.cornell.edu atmgungnir atmvla
166.101.30.54 atmpap.cs.cornell.edu atmsnotra atmpap

We have created 0/250, 0/251, 0/252, 0/253, 0/34 connecting kepler-atm.npac.syr.edu with atmsnotra and atmgungnir. (Robbert VanRenesse - rvr@cs.cornell.edu, Phil Pishioneri - pgp@tc.cornell.edu, David J. Barr - djb1@cornell.edu, Bruce Johnson - bbj1@cornell.edu)

NPAC <-> Rome Laboratory

166.101.10.1 ASX switch
166.101.10.103 mimac-atm.ndf.rl.af.mil mimac-atm.ndf mimac-atm
166.101.10.104 awacs-atm.ndf.rl.af.mil awacs-atm.ndf awacs-atm
166.101.10.105 missouri-atm.ndf.rl.af.mil missouri-atm.ndf missouri-atm
166.101.10.108 cranberry-atm.ndf.rl.af.mil cranberry-atm.ndf cranberry-atm
166.101.10.109 rf2-atm.ndf.rl.af.mil rf2-atm.ndf rf2-atm

We have created 0/32, 0/150 connecting kepler-atm.npac.syr.edu with missouri-atm (Brian Muller - brianm@ndf.rf.af.mil, Jim McCarthy - jimm@ndf.rl.af.mil, Norm Sturdevant - nsturdevant@rl.af.mil)

NPAC <-> Nynex

166.101.210.3 nynex-asx-200 asx-200
166.101.210.5 nynex-atm 9x-syrpdc-atm
We have created 0/35, 0/153 permanent virtual channels connecting kepler-atm. npac.syr.edu with nynex-atm workstation (John Lyon - lyonj@nynexst.com).

NPAC <-> Schools

128.230.98.1-15 NPAC
128.230.98.1 LAX 20
128.230.98.16-31 Fowler High School
128.230.98.16 LAX 20
128.230.98.17 SGI Indy
128.230.98.32-47 Rome Free Academy
128.230.98.32 LAX 20

128.230.98.33 SGI Indy

128.230.98.48-63 Whitesboro Middle School

128.230.98.48 LAX 20

128.230.98.49 SGI Indy

128.230.98.64-79 The Dalton School

128.230.98.80-95 The Ralph Bunch School

128.230.98.96-111 School for the Ph.C

128.230.98.96-111 Rome Laboratory

128.230.98.112 LAX 20

128.230.98.113 SGI Indy

We have defined the following PVCs: NPAC <-> RBS 0/45

NPAC <-> RFA 0/140

NPAC <-> WMS 0/141

NPAC <-> FHS 0/142

NPAC <-> RL 0/143

4.4 ISDN - Integrated Services Digital Network

The ISDN is intended to be a worldwide public telecommunication network to replace existing public telecommunication networks and deliver a wide variety of digital services. The ISDN is defined by the standardization of user interfaces and will be implemented as a set of digital switches and paths supporting a broad range of traffic types (e.g., data, voice, image, video, etc.) and providing value-added processing services. It has been generally accepted and implemented all over the world. ATM is the transfer method of the future Broadband ISDN (B-ISDN), which is expected to support a wide range of services including data communications. As B-ISDN deployment will be gradual and ISDN provides a cheap and efficient access interface, it is envisaged that ATM will not replace ISDN immediately and that both of them will coexist to access the B-ISDN.

We have installed 7 ISDN lines in NPAC. They are used for videoconeferences

using ProShare, InPerson and CLI Eclipse devices. ISDN is installed on 2 SGI Indy workstations (128.230.117.15, 128.230.117.16) with the operating system upgraded to IRIX 5.3. One of these Indys will work as a gateway between ISDN and ATM. Following is a list of characteristics and capabilities that are provided by ISDN technology:

- ISDN provides point-to-point digital communications
- Carry 3 media streams: data, voice, video
- N-ISDN - Narrowband ISDN
  - circuit switching orientation
  - uses 64 Kbps channels as basic unit of switching
  - Basic Rate Interface (BRI) - the most common ISDN service, which is composed of two B channels and one D channel (2B+D = 144 Kbps; B - Bearer Channel (64 Kbps); D - Delta (signal) Channel 16 Kbps)
  - Primary Rate Interface (PRI)- ISDN service, which consists of 23 B channels and one D channel (D operates at 64 Kbps; 23B+D = 1.544 Mbps (T1); In Europe 30B+D = 2.048 Mbps (E1))
  - bandwidth on demand
  - max 1.544 Mbps
- B-ISDN - Broadband ISDN
  - packet switching orientation
  - designed to provide integrated services over Gigabit-speed networks
  - Cell Relay (ATM)

ATM based B-ISDN supports both connectionless and connection-oriented communications, while ISDN is mainly circuit switching and connection-oriented, respectively.

Video Teleconferencing such as Intel ProShare that runs over ISDN can be used to give a remote audience a presentation, collaborate and consult with other remote experts (e.g., discuss patient medical images), and remote demonstrations. The Figure 8 (Appendix D)shows one of the ISDN demonstrations ran in January 1995. In this demonstration, one PC was located at Binghamton, New York and connected through an ISDN network to another PC located at NPAC of Syracuse University. We used Intel's teleconferencing package "ProShare" that was installed in both PCs that were running Windows 3.1. The ISDN number of the NPAC PC was dialled from ProShare to establish contact with NPAC PC users. We used the electronic notebook to share the diagram of the actual layout of this demonstration.

The next application demonstrated was the sharing of a medical image file over the notebook. Medical images, which take around 30 minutes using a 14.4 Kbps modem using an ordinary phone line, were received at Binghamton within a one minute period. Some of the downloaded images included some video clips which could be started at both ends. The experts at both ends could discuss the images using pointers, markers, text and speech.

The last application that was demonstrated over video teleconferencing was the use of teleconferencing for remote demonstrations. In this application, we ran a Parallel/Distributed application, such as the Stock Option Pricing Model, which involved two supercomputers (CM5 and MasPar) and two workstations (SUN and DEC workstation). Using ProShare, the results of this application were shared over the notebook so the remote audience could see the results of this Parallel/Distributed application as if they were local to the site where the supercomputers and the workstations were running this application.

5 Telemedicine Experiment

5.1 Objectives

- Analysis of medical and technical requirements in pathology image processing
  - quality of images (resolution, compression)
  - storage, bandwidth
  - capturing and digitization (scanners, cameras)
  - data acquisition from analog devices
- Acquisition, storing, disseminating and browsing of multiresolution images
  - digitization at low and high resolution and high-speed transmission of images
  - compression with variable degrees of "lossy" factor
  - store, catalog, sort, retrive and send
- Early prototype of 3D virtual tour through tissue - 3D reconstruction from serial sections
- Initial investigation of requirements and algorithms for automated identification of strange patterns
- Telemedicine NYNET demonstration setup in cooperation with SUNY Health Science Center - Participation in the Telemedicine Conference in Syracuse, OnCenter, 23-26 April 1995

5.2 Analysis of Medical and Technical Requirements in Pathology Image Processing

Telemedicine is the delivery of healthcare through interactive audio, video or data communication. The U.S. government devoted for telemedicine at least $25

million in fiscal 1994, according to the Center for Public Services Communication. This sum doesn't include one of the biggest spenders, the Department of Defense. Telemedicine is supposed to make healthcare more accessible to patients, particularly in rural areas. It will improve medical care and save money because rural patients and big-city specialists won't need to travel to see each other. One controversial, but often-cited, study says that telemedicine could reduce U.S. healthcare costs by $36 billion annually. However, telemedicine's cost-effectiveness still remains a question.

Pathology is a medical specialty which makes use of images to a significant extent. However, up to now, the digital image technology is used only in minimal degree. This contrasts sharply with specialities such as radiology, cardiology and nuclear medicine, which have incorporated digital imaging for over a decade. This disparity can be explained partially by the need of color and high resolution (the color image processing dates from 1990). The standard methodology for image archival within the realm of pathology has been and continues to be the glass slide itself and the 35mm slide. Tissue is removed from a patient via an open surgical biopsy, needle biopsy or a fine needle aspiration. From the tissue, many types of material are produced including glass tissue slides, diagnostic gels, video and photographs of specimens. Once the glass slides have been produced, they are presented to the pathologist for review and diagnosis. Each slide degradates very quickly (15 days). Digitizing the images taken from the slides will extend significantly the life-time of the stored material.

Telepathology includes the transfer of the digitized pathology images over distances for consultative purposes. High speed networks (ATM) and computers can have a major impact on medicine in the near future.

As a result of several meetings with neuropathologist Dr. Robert Corona, Physician Director of Telemedicine and Medical Informatics at SUNY Health Science Center and biophysicist Dr. Edward Lipson, Professor and Acting Chair in Department of Physics in Syracuse University, we defined the medical and technical requirements for image acquisition, analysis and processing in telepathology.
Following is a list of the telepathology requirements:

- Up to now the digital image technology is used only in the minimal degree in pathology
- The pathology still depends on visual observation through the light microscope (max 400 magnification); this process will be replaced in the future by automatic data acquisition with the use of a CCD camera and microscope connected to a computer.
- Acceptible resolution for still images: 2000x2000 pixels; we should have the ability to see objects of 4μm in diameter; in literature, 1000x1000 is said to be sufficient.
- 24 bit color map is required (16.7 million colors); however the human eye theoretically supports only the perception of about 10,000 different colors simultaneously; there is much disagreement about this figure, but it is definitely lower than 16 million.
- One image without compression requires 12 MB of disk space (if we assume 2Kx2Kx24)
- There are about 10,000 images created in one hospital in NY state per year (120 GB/year); some of them should be stored for future reference
- There are no standards describing pathology images (as DICOM 3 in radiology)
- In radiology, cardiology and nuclear medicine, digital imaging (MRI,CT,PET) has been incorporated for over the past decade (PACSystems). The DICOM 3 standard was developed and adopted.
- The application of any lossy compression technology in the medical area creates some controversies: the critical feature of any lossy compression is what is important and what is not.
- The security and legal issues are extremely important

In this project, we designed a prototype of a **pathology workstation** [Appendix D, Figure 9] which can support but definitely not replace, the work of neuropathologist. The pathologist's workstation is a combination of hardware, software, databases and interfaces. It should consist of the following components:

- remotely driven microscope
- high-resolution CCD (Charge Coupled Device) camera
- workstation for image viewing (Unix, large-screen, high-resolution color monitor, remote control)
- archiving system (image storage)
- high-speed network connection (ISDN/ATM)
- slide scanner/slide maker
- backup devices
- color printer

The desirable capabilities of the imaging system include the following:

- multitasking, multiple windows on the screen
- easy to use, menu driven graphical interface
- immediate task switching
- network connection (LAN, Internet)
- videoconferencing (electronic consultation)
- multimedia mail
- access to databases (patient records, images)
- software (word processor, virus protection)

- expert systems: knowledge-based systems implemented with the use of more sohisticated techniques, including neural networks, decision analysis and fuzzy logic.

- locking software and safeguarding of patient data.

Security and access control are perhaps even more crucial than other aspects. Patients expect their information to be treated confidentially. Security policies must be defined and implemented to protect laboratory data against unauthorized modification, inappropriate access and breach of patient confidentiality.

We took the first step toward making a high resolution microscope and professional digital camera accessible to physicians via the high-speed network. Normally, doctors sit at the microscope and look at different views of the sample with several magnifications. The **Pathology Workstation** prototype puts the control of the microscope at the researcher's remote workstation. They can compare and analyze images while online with microscope. Microscopists uses a graphical interface on their own workstation to interact with the microscope's capture/control workstation and the supercomputers in NPAC. A microscope operator performs tasks (focusing) that cannot be done remotely. Powerful computers are used for:

- databases of high resolution images and other multimedia information

- compression and decompression of images

- volume rendering and 3D reconstruction from serial sections

For example, when the researcher requests the 3D reconstruction, the capture/control workstation collects hundreds of images and stores them in the compressed form in the parallel database. The rendering program aligns them and produces a volumetric dataset. The result is sent to the researcher's workstation. We want to integrate high-speed networks, high-performance computing, image processing and image analysis.

High-Speed Networking

The importance of this technology to the telepathology project is clear, since multi-megabyte pathology (neuropathology) data files must be transferred rapidly to the experts capable of performing the diagnosis. NPAC is exploring not only the new ATM communication technology (being a partner in the NYNET regional ATM network), but also the ISDN connections across the nation. These networks are used for data transfer and as a desktop video telecollaboration testbed.

High-Performance Computing

NPAC computing facilities include machines such as Thinking Machines CM-5, IBM SP2, nCUBE 2, Intel i860, Maspar DECmpp and a cluster of DEC Alpha workstations. Since medical image analysis is computationally very intensive, NPAC is well prepared to act as a provider of massively parallel computing to physicians in hospital(s). Access to such computing power allows physicians to do real time consultations supported by image analysis.

Image processing reflects an operation where a source image is processed, producing output image. It consists of the removal of unnecessary information and the rendering to a more useful state by some set of functions. Image analysis allows extracting some type of useful data from an image. The following issues must be addressed:

- thresholding - converting a color image into a two-tone black and white image (useful in the counting of cells)
- color space evaluation - separation of hue, saturation and intensity (so called HSI system)
- cellularity determination
- digital filtering, dithering, color reduction

Image analysis consists of:

- image acquisition (capturing) and digitization
- compression/decompression of high resolution, full color images: wavelets
- image storage/retrieval to/from parallel databases
- visualization tools (2D images), zoom in/out
- pattern recognition which directs the physician's attention to a suspect area
- edge detection: Marr, Sobel, Random Markov Fields
- edge linking: Hough Transform, Green's Function, local methods

We concentrated on the storage and efficient retrieval of very large images. Compression of the image data is a primary concern since it improves the utilization of storage and transmission resources. The compression technology incorporates the DWT (discrete wavelet transform).

5.3 Acquisition, Storing, Disseminating and Browsing of Multiresolution Images

ACQUISITION

- The acquisition station built in this project consited of an Olympus AX70 microscope, CCD high-resolution Kodak DCS420 digital camera (SCSI interface), Sony CCDSSCS20 camera and an SGI Indy workstation with a high-resolution monitor.
- We received 19 images representing the slices of the human brain [Appendix D, Figure 10]. They are written in the Kodak's PhotoCD format on the CD ROM in 19 separate files. Each file (4MB) contains 6 forms (components) of the image with various resolutions: 96x64, 192x128, 384x256, 768x512, 1536x1024 and 3072x2048 pixels. These images can be displayed, stored, copied and converted to other formats using the following tools:

- SGI ImageVision Tools (imgcopy, imgworks, imgview, imginfo)
- MacIntosh (PhotoShop, PictureExchange, Fetch/Aldus)
- IBM PC (Picture Publisher).

We have converted the PhotoCD format to RGB and GIF image formats and created movie sequences by using the 'moviemaker' SGI tool. These images are available on the Project Information Server in http://kopernik.npac.syr.edu:1200/images/PhotoCD/brainicons.html. However, the slices cannot be aligned properly and are not useful for the further study.

- We scanned 20 typical neuropathology images (different brain tumors; magnification = 400 times) as well as 20 cytology and 20 histology images [Appendix D, Figure 11]. We received them on 35mm x 24 mm slides. They were scanned on a Nikon "Coolscan" scanner connected to a MacIntosh Centris 650, stored in uncompressed JPEG format and sent over the network to the Project Information Server (http://kopernik.npac.syr.edu:1200/images/index.html).

- We have also 6 pathology images. They were scanned on a Nikon "Coolscan" scanner connected to a MacIntosh Centris 650, stored in GIF format and sent over the network to Information Server. They are accompanied by related audio annotations done by Dr. Bob Corona (http://kopernik.npac.syr.edu:1200/images/AUDIO/audio.html)

- We have installed the RUN_KODAK program written by Bob Kozdemba (koz@sgi.com). The program allows a user to capture images from a Kodak DCS420c camera and store them on SGI Indy. The program can be used locally (on an SGI connected directly to a microscope and camera) as well as remotely. The user interface is fairly straight forward to use. First, select a light source from the 'Color Balance' menu. A picture can be taken by selecting 'Take Picture' under the 'Camera Control' menu or an existing DCS TIFF image can be read in by opening the file itself. Under the 'Image' menu, there are 2 choices, 'Preview' and 'Acquire'. Preview will scale, color balance and color correct a 768x512 size image. It should take around 15 seconds depending

on the CPU. Acquire, in addition to the functions performed by the previewer, will interpolate the final 1536x1024 image using Kodak's algorithms and should take around 1 minute.

COMPRESSION

- We investigated different compression technologies including:

  JPEG - a leading standard in image compression mechanism. JPEG stands for Joint Photographic Experts Group, the original name of the committee that wrote the standard. JPEG is designed for compressing either full-color or gray-scale digital images of "natural", real-world scenes. It does not work so well on non-realistic images, such as cartoons or line drawings.

  JBIG - which losslessly compresses binary (one-bit/pixel) images. (JBIG stands for Joint Bi-level Image experts Group).

  Fractal - A promising new technology, arguably superior to JPEG – but only with an argument. It is a lossy compression method. The fractals in Fractal Image Compression are Iterated Function Systems. It is a form of Vector Quantization, one that employs a virtual codebook. Resolution enhancement is a powerful feature but is not some magical way of achieving 1000:1 compression. Compression is slow, decompression is fast. The technology is patented.

  Wavelets - rediscovered in 1987, lossy compression with high compression ratio (more than 100:1), excellent mathematical background, compresses the images as a whole. The full extensive description is available on http://kopernik.npac.syr.edu:1200/compression/tutorial.html as well as in Appendix B.

- After the study of JPEG, JBIG, fractal and wavelet compression methods, we decided that the WAVELET compression/decompression scheme is the best suited for pathology image processing [Appendix D, Figure 12].

- We have investigated existing WAVELET compression software including the following (http://kopernik.npac.syr.edu:1200/compression/wavelet.html):
  - **HCOMPRESS** - 25 programs, 3000 lines of code - the image compression package written by Richard L. White for use at the Space Telescope Science Institute (rlw@stsci.edu). Briefly, the method used is:
    * a wavelet transform called the H-transform (a Haar transform generalized to two dimensions), followed by
    * quantization that discards noise in the image while retaining the signal on all scales, followed by
    * quadtree coding of the quantized coefficients.

    The technique gives very good compression for astronomical images and is fast, requiring about 4 seconds for compression or decompression of a 512x512 image on a Sun SPARCstation 1. Consequently, the program can be used for either lossy or lossless compression, with no special approach needed for the lossless case.
  - **EPIC** - (Efficient Pyramid Image Coder) is an experimental image data compression utility written in the C programming language. The compression algorithms are based on a biorthogonal critically-sampled wavelet (subband) decomposition and a combined run-length/Huffman entropy coder. The filters have been designed to allow extremely fast decoding on conventional (ie., non-floating point) hardware, at the expense of slower encoding and a slight degradation in compression quality (as compared to a good orthogonal wavelet decomposition). EPIC is currently limited to 8-bit monochrome square images, and does not explicitly provide a progressive transmission capability (although this capability is easily added since it uses a pyramid representation). EPIC is available via anonymous ftp from whitechapel.media.mit.edu (IP number 18.85.0.125) in the file pub/epic.tar.Z. The decompression command "unepic" is also provided.
  - **IMAGER LIBRARY** is available via the Web at the "Wavelets at Im-

ager" home page. The URL is http://www.cs.ubc.ca/nest/imager/ contributions/bobl/wvlt/top.html and it is accessible via the Wavelet Digest home page.

- **ACCUPRESS FOR MULTIMEDIA** Is a commercial software from Aware Inc (http://www.aware.com), available in both DOS and Unix versions. It supports 8-bit gray scale and 24 bit color imges in raw and TIFF formats. The compression ratio can be varied over a wide range (6:1 - 150:1, for 24 bit TIFF). We used AccuPress mainly for compression of pathology images; compression ratios, upto 40:1 are acceptable for our application. Our source files are 24 bit TIFF's composed approximately 900x600 pixels. The compression and decompression executables are invoked with command line arguments, where values of compression ratios, file formats, source and destination paths are specified. A binary executable file, diffimages, also from AWARE, can be used to compute error statistics between the original and the decompressed images. We have found it to be a useful starting point for our error statistics module. Some of our results are available on
http://kopernik.npac.syr.edu:1200/compression/wavelet/result.html.

STORING AND BROWSING

- The demo version of a Computer-based Patient Record Database has been prepared. The patient data (texts, audio, images, movies) are stored in the Oracle database. The Patient Record Database was demonstrated during the Telemedicine Conference in Syracuse, April 23-25.

- The Web based database server has been built for a patient record system which consists of patients' personal information (e.g. name, ID number, sex and age), textual medical information (e.g. chief compliment, results of exams, history) and multimedia medical information (images, audio and video). Patient records can be guarded by a security password. It requires appropriate username/password to modify, insert and delete patient records. By using a

CGI gateway program, text or multimedia files can be remotely retrieved from a specified Web server to another Web server; wavelet compression for image files can be optionally performed by users.

- PL/ SQL has been used for data manipulation and processing. PL/SQL is a database programming language with expressive capability between SQL and C/C++ (loops, decisions, modules, functions, etc.). Therefore, the database server is both an SQL engine and a compute engine which can generate programmable and dynamic Web pages.

- A client-server model is implemented in this application [Appendix D, Figure 13]. A Web client issues a request to a Web server via an HTML fill-out form. The gateway interface translates the request into a relational database SQL query and passes it to database server. The database server executes the query and sends the query results to a Web client via a gateway interface and a Web server. In this way, the Web client can access and retrieve information from a remote database server in real time.

- Images have been stored with some textual/audio information in the Oracle 7 database. Oracle RDBMS is installed on an IBM Power Station. After an investigation of existing WWW Oracle gateways (http://dozer.us.oracle.com:8080/), we have installed WOW (Web Oracle Web - http://dozer.us.oracle.com:8080/sdk10/wow/) . This software is a tool for developing gateways in a specific environment: PL/SQL stored programs. The gateway interface permits connectivity between a medical (or other) database and the full power and scope of the Internet.

- Audio annotations are stored in Sun/NeXT and/or AIFF format

- Movie clips are converted and stored in MPEG format

- We wrote and installed the interface for storing the images from the client to server and running the wavelet compression program from the Netscape client side. We installed it on our Project Information Server in the cgi-bin directory

and encapsulated it in a POST query program. By using a Web browser, a user can retrieve files from the Web and store them in a server. The progarms are written in PL/SQL, C and Perl. Generally, this process involves four computer hosts:

1. remote host where the source file is retrieved (specified by user)
2. remote host running an Oracle database server (IBM Power Station)
3. remote host where the retrieved file is stored (need SGI Challenge for Wavelet compression)
4. local host where the user is running a Web browser

- We wrote a CGI program to compress image files by using the Wavelet method. A database user can choose to do image compression while retrieving image files from the Web. After retrieving, the compressed image is decompressed. All images (original, compressed and decompressed) can be accessed by their own URLs. The compression ratio can also be specified by the database user.

5.4 3D Reconstruction Of Human Head

Introduction [1]

Reconstruction is the abstract *rebuilding* of something that has been torn apart. In the medical imaging context, it is often necessary to acquire data from methods that essentially *tear* the data apart (or acquire the data one piece at a time) in order to be able to view what's inside. Also, a big part of reconstruction is then being able to view, or visualize, all the data once it has been put back together again. In this project, we have reconstructed the human head from the Visible Human MRI data set available via ftp. State of the art tissue identification and surface reconstruction algorithms are used to identify the polygons forming the surface of interest. Standard computer graphics algorithms are then used for rendering these polygons. Viewing transformations are also applied for 3D rotations of the reconstructed head. The original data set consists of 28 slices of MRI scans of the head spaced 4 mm apart. This report describes the algorithms used and some of the results obtained using this approach.

The following are some real world examples of reconstruction:

• Serial-Section Microscopy:

In Serial-Section Microscopy, the tissue being studied is sectioned into a number of slices and each slice is put under a microscope. Then, images are captured for each slice. To recreate how the tissue looked before we sectioned it, we must put the images of all these slices back together, just as if we were putting the real slices of tissue back together again.

• Confocal Microscopy:

In confocal microscopy, the microscope can obtain a single plane of image data without having to slice the tissue. In this case, we do not need to realign the images of the slices much, but just stack them back together and then visualize the result.

• CAT (Computed Axial Tomography):

In CAT, the scanner acquires a number of projections, much like an X-ray, from

[1] This paper is to be published in Syracuse Center for Computational Science (SCCS), NPAC technical report, The author is Srividhya Narayanan.

different positions. Then, these different views through the object (or person!) must be "deconvolved" (meaning combined) to reconstruct the 3-dimensional object.

• MRI (Magnetic Resonance Imaging):

In MRI, the imaging device acquires a number of cross-sectional planes of data through the tissue being studied. Since all of these planes must be stacked back together to obtain the complete picture of what the tissue was like, MRI entails some amount of reconstruction and lots of visualization, too.

In this work we use MRI data for a human head to reconstruct part of the skull; the data is available as MRI slices spaced 4mm apart. Each slice is 4mm thick with a 256 x 256 data matrix and a field of view of 24 cm. The resulting pixel dimension was 0.94 x 0.94 cm.

The entire reconstruction pipeline is shown in Figure. 1. The tissue of interest, is first isolated from surrounding data using a region growing method - a connectivity algorithm. The masks set at this step are used at the next stage - the marching cube algorithm. This algorithm identifies polygons that make up the surface of interest for each cube constructed on the data matrix. Normals are computed for the polygon vertices and are passed to the next step in the pipeline - the visualization step. The visualization step involves constructing the 3D transformation matrix for any rotations to be applied at this stage to obtain a different view of the rendered image of the head. This viewing transformation is applied to all the polygons and the vertex normals. The light intensity at each vertex is then computed using a diffuse illumination model with a directional light source. The polygons are then passed to the z-buffer algorithm for visible surface determination. The Gourad shading algorithm is applied at this stage to interpolate the intensity values from the vertices to every pixel in the polygon. The polygons are then displayed using X library functions to show the image of the head.

In the following sections some of the details of the various steps outlined above are discussed. First, we briefly describe the connectivity algorithm; the interested reader is referred to the literature for details on this algorithm. We then go on to introduce the marching cube algorithm, once again the reader is directed to the literature for

details on this algorithm. Next, we describe the rendering steps involved in the visualization of the surface identified in the preceeding step. We follow this with implementation details for the various steps. In conclusion we discuss the state of the present work and future development of this software.

Reconstruction Pipeline

Figure. 1 shows the various steps in the reconstruction process. This is a complex process and involves isolating the tissue of interest from its surroundings, identifying the polygons that form the surface of interest and visualization of the surface. Each of these steps is described in a little more detail in the following sections.

Connectivity Algorithm: The connectivity algorithm is a region growing algorithm that distinguishes the desired surface from its surroundings despite similarities in signal intensities and complex morphology. This algorithm requires a user defined seed pixel on each slice to mask out regions that are not of interest. This seed point is manually selected, a mask of 1(or 0 if the seed point is outside the surface of interest) is set for each pixel that is connected to the seed point. Each connected point in turn now becomes the next seed point and points connected to it are identified and tagged. This therefore constitutes a region growing process which is continued for all active points until there are no more connected unmarked pixels. For details on this algorithm and some results obtained using this technique please refer to [1].

Marching Cubes Algorithm: The marching cubes algorithm creates triangle models of constant density surfaces from 3D medical data. Marching cubes locates the surface in a logical cube created from 8 pixels - 4 from the current slice and the other 4 from the adjacent slice. The masks for these pixels is set in the connectivity algorithm step and identifies which of these pixels fall inside the surface of interest and which fall outside this surface. The surface of interest, in our case the skull, intersects those edges of the cube for which one vertex falls inside and the other outside the surface. The location of the point of intersection is obtained by linear interpolation based on the surface density value and the vertex pixel intensities.

An index array is set for each cube that is processed based on the mask values

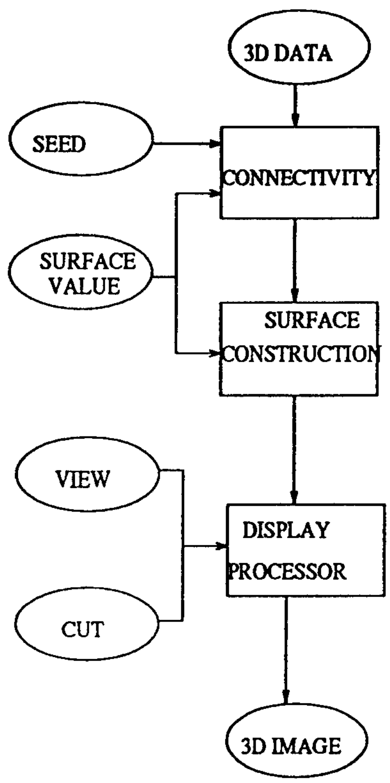


Figure 1: Connectivity method of selecting a tissue

for the vertex pixels. This index array is used to identify which of the 14 basic patterns the mask set for the cube corresponds to. The table of complements and rotational symmetries for the base pattern identified is looked up to find a match of the table entry with the bit pattern in the index array. This yields the surface-edge intersections for the current cube. The polygon vertices are obtained by interpolating the cube vertices for the intersected edge. For a surface of constant density the density gradient vector is normal to the surface. The surface normal is therefore obtained by computing the surface gradient vector, the normalized gradient vector yields the surface unit normal. This unit normal is used in the shading algorithm. To obtain

this normal at the surface, the normals at the cube vertices are first computed using a central difference formula for the cube vertex densities. At edge slices and at the boundaries of the current slice either forward or backward differences are used based on the position of the boundary. These normals are then interpolated to the polygon vertices to obtain the normal for each polygon vertex. Details of the marching cubes algorithm are described in [2].

Rendering Pipeline: The rendering pipeline is illustrated in Figure 2. Each of the steps in the pipeline are described in some detail in the following sections.

Modeling Transformation: Associated with each slice that is processed is a local coordinate system fixed at the origin of the data matrix for that slice. The marching cubes algorithm is applied to a set of 4 such slices at a time and is run on a subregion that lies within a local bounding box defined on these 4 slices. The polygons constructed in this step have coordinates based on the 3D modeling coordinates. Modeling transformation is applied to transform these object coordinates to the world coordinates. The world coordinate system is defined on a global bounding box consisting of all the slices with origin fixed to the origin of the lowermost slice.

Viewing Transformation: The viewing transformation matrix is constructed depending on the desired amount of rotation to be applied to the head. Presently only rigid body rotational transformations are supported; the head is rotated about the centroid of the bounding box. To achieve this, the bounding box centroid is first translated to the origin of the coordinate system, the desired rotation is then applied and then the bounding box is translated back to its original position. The 3D transformation matrix is constructed by a composition of these translations and rotations (T_2RT_1). Since the normals are specified with the polygons at this step, these normals must be transformed correctly during this stage. The viewing transformation matrix for the normals consists of only the rotation matrix R since rigid body rotations preserve angles and only affect the orientation of the polygons. For arbitrary transformations, the transformation matrix for normals must be constructed separately to ensure that the normals are perpendicular to the polygon surface.

Lighting: The head is lighted using diffuse illumination with a directional light source. This model uses a point light source located sufficiently distant from the

object so that the light rays make essentially the same angle with surfaces which have the same orientation. Thus $\overline{L}$, the light ray vector, is a constant for the light source. A property of surfaces exhibiting diffuse reflection is that such objects appear equally bright from all viewing angles since they relect light equally in all directions. The intensity depends only on the angle θ between the direction $\overline{L}$ of the light source and the local surface normal $\overline{N}$. The diffuse illumination equation is therefore:

$$I = I_p k_d cos(\theta) \tag{1}$$

where I_p is the point light source's intensity; k_d is the material's diffuse reflection coeffecient and is a constant between 0 and 1 and the angle θ is between 0 and 90 degrees. If the vector $\overline{N}$ and $\overline{L}$ are normalized then the intensity equation can be rewritten as:

$$I = I_p k_d (\overline{N}.\overline{L}) \tag{2}$$

Since we use a directional light source $\overline{L}$ is a constant in the above equation.

Visible Surface Determination - The z-buffer Algorithm: Visible surface determination is done using the well known z-buffer algorithm. A broad outline of this method is given below:

- A Z Buffer and a Frame Buffer of the same size of the display screen are initialized with zero and values of the background intensity respectively.
- Polygons are scan converted one at a time.
- If the Z value of the new point calculated is no farther than the existing value in the Z Buffer then replace it with the new value and update the Frame Buffer with the intensity value of the point.

The z value for each new point on the polygon is computed using the equation:

$$z = z_1 - \frac{A}{C}(\Delta x) \tag{3}$$

where z_1 is the z value at point (x, y), A and C are the polygon plane coefficients and z is calculated at point $(x+1, y)$.

Gouraud Shading: We use an interpolated shading technique to shade the polygons starting with intensity values calculated at each polygon vertex using the lighting model described above and Gouraud shading to interpolate these vertex intensities to points in the polygon. The polygons are shaded by linear interpolation of vertex intensities along each edge and then between edges along a scan line. For efficieny this step is incorporated into the z-buffer algorithm itself.

Rasterization: This step is incorporated into the z-buffer algorithm during the scan conversion of the polygon edges. The edge table is constructed such that the first edge uses the closest pixel to the current point on the line and the second edge always uses the closest point that lies inside the polygon.

Display: The frame buffer is written out to be visualized on the display device. Some transformation may be required at this point to conform to the 2D coordinate system of the display software. In our case, Xlib was used to display the image; the origin of the screen coordinates are fixed at the top left corner of the window. The frame buffer therefore had to be managed to orient the image to this coordinate system.

Implementation

The implementation of this software has been tested on the SGI ONYX platform running Irix 5.3. We have reconstructed sections of the MRI head data set (28 slices in transaxial sections with 4mm spacing between slices) from the Visible Human Project. This involved the following steps and algorithms

1) Surface detection: used to get rid of the uninteresting data for reconstruction

(e.g gelatin layer surrounding the head data)

2) Marching Cube Algorithm: to get the polygons forming the surface

3) Z Buffer Algorithm: used for visible surface determination

4) Gauraud-Shading: for rendering

5) Display using Xlibraries.

Surface Detection - The Connectivity Algorithm It is basically a Breadth First Search. A pixel is intialized as the seed point which lies outside the surface to be detected. All the pixels in the image are set to a mask of 1. A queue of seed points is maintained. The density of every pixel in the seed queue is compared with its four adjacents as follows:
pixel [x] [y] is compared with

- pixel [x + 1] [y]
- pixel [x - 1] [y]
- pixel [x] [y + 1]
- pixel [x] [y - 1]

such that if no change in the intensity occurs, then the pixel is added in the seed queue and its mask is set to 0. If there is a change in the intensity, then the mask of the pixel is set to 1 and it is not added in the seed queue and its adjacencies are not compared. Once a pixel is compared with all its adjacents, then it is dequed and is set to some specific index so that when the procedure is repeated in the rest of the "set of pixels", the same pixel is not visited again. Each slice is a 256 x 256 point matrix with a field of view of 24 cm resulting in a pixel size of 0.94 x 0.94 cm. The result of this program on the data set(Visible Human Project, MRI head data) is a data matrix with the data points/pixels inside and at the boundary of the head set to a mask of 1 and the rest(the gelatin part of the MRI image) set to a mask of 0 [1].

This data set gives a value of either 1 or 0 for all the vertices of the cubes to be formed later when applying the Marching Cubes algorithm.

Marching Cubes Algorithm This is the critical step in the reconstruction process since the polygons defining the surface of the head are formed at this stage. There are many issues connected to this algorithm involving implementation as well as efficiency considerations. In this section we briefly describe some of these aspects; the reader is referred to [2] for implementation details related to this specific technique.

This algorithm is applied to a slice at a time; to construct the cubes between two adjacent slices requires reading 2 slices into memory. Furthermore, since central differencing is used in the computation for the normals, 4 slices are currently read into memory for each slice that is processed. A bounding box is constructed for the set of four slices; the marching cubes algorithm is now run only inside this box. This reduces the processing time by avoiding running the algorithm on regions that clearly are outside the slices. Each slice is processed from the minimum x and y coordinates and marched to the maximum x and y coordinates of the bounding box. For each data point, a logical cube is constructed from the adjacent points on the current and adjacent slices. The mask values from these points is read into the index array to construct a bit pattern for the current cube. This bit pattern is now investigated to determine which of the 14 base patterns it corresponds to; these 14 base patterns identify the topology of the surface within the cube. Complements of the index array are taken where required. Care must be taken in correctly identifying the pattern since the triangles are constructed based on these identified patterns.

The cube vertex normals are now computed using the density values stored at the cube vertices. Central differencing is used except at the boundary slices and the boundaries of the current slice where forward or backward differencing is used as appropriate. The boundary points are processed separately from the internal points to enhance the performance of this function.

The triangles forming the surface are now identified by looking up a table of complements and rotational symmetries corresponding to the base pattern identified in the preceeding step. The triangle vertices are now obtained by linearly interpolating the cube edge vertices based on the density value of the skull surface and the cube vertex intensity values. The normals from the cube vertices are also similarly inter-

polated. The triangles corresponding to some of the base patterns can be determined by looking up the vertex list for the intersected edges and does not require the more expensive table lookup required for the other patterns. A global bounding box is also formed after the execution of this algorithm on all the data slices.

The polygon vertices and vertex normals are then written out to be used in the rendering process. Using a logical cube formed from adjacent pixels gave rise to sliver polygons; this led to problems during the scan conversion of these polygons. The resulting surface was also rather rough; to smooth out these effects, antialiasing was used. The data matrix was reduced by averaging four pixels into one and the marching cubes algorithm was then run on this reduced data set. The polygon vertices were then mapped back to the original data set to preserve the original dimensions of the head.

The Z-buffer Algorithm The polygons obtained from the Marching cube algorithm are rendered using the Z buffer algorithm. The z value at each pixel in the scan line is calculated and the Z buffer is updated depending on whether the polygon is visible or not. The frame buffer is also updated whenever the Z buffer is with the values of the intensity calculated by the Gouraud Shading. The implementation follows the algorithm described in [3]. The frame buffer is displayed using X with intensities values for all the pixels.

Gouraud Shading The diffuse illumination equation is used with a directional light source of intensity 1.0 with the diffuse reflection coefficient of the head set to 0.5. The light source was directed at an angle of about 50 degrees to the screen surface and normal to the screen y-axis. The pixel intensities were determined by linearly interpolating between the maximum displayed intensity(for points whose normals were perpendicular to the light) and the minimum intensity(for points whose normals are directed along the light ray) depending on the angle θ formed by the local surface normal and the light source.

The intensities calculated for the polygon vertices were then linearly interpolated along the active edges of the polygon in the z-buffer algorithm. The intensities were then linearly interpolated along the current scan line between the intensity values at the polygon edges on the current scan line.

Results

The original slices from the MRI scan are transaxial slices of the head. There are 28 such of them from which polygons are created and then rendered.

Conclusion

The reconstruction and rendering algorithms uesd in the development of this software have been described in this document. The reconstruction technique works satisfactorily for the data set used herein. However some improvements are needed to smooth out the surface. Also a user friendly GUI needs to be developed for the system and the display of the images needs to be improved. Due to time constraints some of these aspects could not be currently implemented.

This software can be developed in the future to add capabilities to fly through the head dataset.

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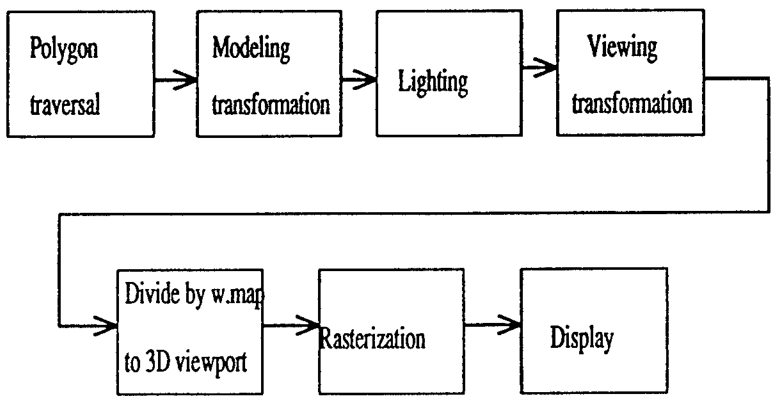

Figure 2: Marching Cube Algorithm

5.5 Pattern Recognition

5.5.1 Initial Investigation

The following are the requirements and algorithms for automated identification of strange patterns from our initial investigation:

- The "strange patterns" in tissue can be classified according their shape, color, dimension and concentration of cells in comparison with other surrounding objects.

- Most cells are roughly spherical and consist of the nucleus, the cytoplasm and the cell boundary. The tumor is any mess or growth of abnormal cells. Many types of tumors can develop in various locations (skull, brain membranes, supportive tissue, cranial nerves, etc.) and each has its own symptoms, treatment and prognosis. Generally, there are 2 types of brain tumor

    1. benign (usually curable)

2. malignant tumor (cancer)

- Pathologists look for clusters of cells and cells themselves. Abnormal cells are usually bigger, darker and less circular.
- It is impossible to give a diagnosis on the basis of one image analysis. It requires years of training and is extremely difficult to automatize.
- We started the investigation of wavelet technology in the area of object detection procedures. One of the major drawbacks in pattern recognition is that the wavelet transform is not translation invariant. In other words, when the input signal is shifted, the wavelet coefficients are not shifted, but instead can change completely. An idea of Mallat and co-workers is not to work with the (discrete) wavelet coefficients but rather with the local maxima of each continuous wavelet band. These local maxima somehow correspond to the edges of the image. For a specific class of wavelet, this leads to the classic Canny edge detector. Edges typically correspond to locations where the image is non-smooth or where it has singularities. The appropriate software can be obtained from: ftp://cs.nyu.edu/pub/wave/wave2.tar.Z.

5.5.2 Pattern Recognition of Pathology Images

Introduction [2]

In this effort,we surveyed the state of the art of pathology image technology and compared it with the more mature image technology for radiology, cardiology and nuclear medicine. Algorithms that may be used for pattern recognition (PR) of pathology images are discussed in detail. Based on the discussion and survey, optimal algorithms for PR of pathology images are suggested and explained.

We investigated the special requirements for PR in the area of telemedicine. Since high accuracy is needed for diagnosis of diseases, algorithms for automated identification of strange patterns (e.g. cancer cells) in pathology images are proposed. Because of the accuracy requirement, probability of error is minimized to the most extent during the classifier design process. Images with any undetermined areas will be manually processed by pathologists.

Pathology is an imaging technique in medicine which deals with the nature of disease (structural and functional changes in tissue). Compared to radiology imaging technology, pathology imaging technology is a relatively new area among medical imaging techniques. Its need of color and high resolution makes the use of digital image technology very difficult to implement.

The standard methodology in pathology is as follows. First, get a sample of tissue via an open surgical biopsy, needle biopsy or a fine needle aspiration. Then, make glass tissue slides with diagnostic gels and take video and photographs. Finally, pathologists can review the glass tissue slides with a microscope and make a diagnosis. The main drawbacks of this standard methodology are: glass slides degrade very rapidly (15 days) and it poses a hard physical work on pathologists who have to review the glass slides manually. By digitizing the images from the tissue slides, not only can pathologists be relieved from hard labor, but also the life-time of the slides is extended (digitized images can be stored forever). In addition, digitized pathology images can be remotely transferred via computer networks, which is an

[2]This paper is to be published in Syracuse Center for Computational Science (SCCS), NPAC technical report. The author is Jiangang Guo

essential requirement for telemedicine.

Pathology Images

Since pathology is a medical technology dealing with human patients, it requires the pathologists' diagnosis to be accurate. Thus, image quality in the client site must be good enough for diagnosis purposes and the pattern recognition algorithm must be able to identify abnormal cells or regions. The original quality of images (in server side) could be 2000x2000x24 (color). In order to store and transfer these images efficiently, data compression has to be applied. Our goal is to keep the loss of information due to data compression to the lowest extent (acceptable by pathologists) while the data transfer speed must be fast enough for real time control.

The following characteristics are important to the diagnosis of disease: color and paleness of tissue; size, shape and density of cells; clusters of cells and number of abnormal cells. In the following section, we will use these parameters as feature elements in our feature space.

Medical Pattern Recognition

Pattern recognition is method of classifying input data into identifiable classes by the use of significant feature attributes of the data (sample). The feature attributes are extracted from a background of irrelevant detail.

Pattern recognition in general can be considered as the classification of objects based upon characterization knowledge and can be separated into four phases:
(1) observing the attributes or characteristics of the objects
(2) selecting useful features from the set of characteristics
(3) making the classification decision, and
(4) evaluating the classification performance.

Many computer-aided techniques have been developed for the analysis of medical images, but their effectiveness is very often application dependent. This is analogous

to the fact that pathologists adopt different strategies to analyze different types of medical images. In addition, different imaging processes will produce images with different characteristics which in turn affect the effectiveness of a given image processing technique.

The standard pattern recognition process includes the following major steps:
(1) data acquisition by transducer (sensor)
(2) data processing (feature extraction)
(3) classification.
The accuracy of classification depends on classifiers (decision functions) which are obtained via priori knowledge learning.

Data Acquisition

Transducers are devices designed to sense the input (physical) variables and transform them into a suitable form for digital processing. Image acquisition devices (microscope, camera) are used to capture images from pathology tissue samples.

Processing on continuous data is relatively less efficient than that of digitized data. In our application, we will try to digitize some of the variables (feature elements) such as the shape and paleness of cells (i.e., making them into discrete quantities). The data set should be divided into a training set and a test set. The training sample set is used to generate pattern classifiers (decision functions) for our specific group of samples. The test sample set is used to check accuracy of the obtained classifiers. The final diagnosis will be made on the basis of a combination of the clinical and laboratory data.

Feature Extraction

After the raw data (digitized pathology images) is captured, feature attributes are extracted to form a feature vector which consists of feature elements (attributes) in feature space. A pathology image is a photograph consisting of many cells or clusters of cells, and nerves connecting these cell/clusters. Our strategy is to identify

individual cell units (cells or clusters of cells) and then try to extract necessary feature attributes from these individual cell units. We also will extract some collective feature attributes for the whole pathology image and some attributes for the nerves if necessary. A hierarchy model will be implemented, i.e., the whole image will be partitioned into smaller areas with special interest for more detailed study.

As mentioned above, a feature vector of a cell unit includes the following feature elements:

(1) color

(2) paleness (brightness)

(3) size

(4) shape

(5) density of cells in its surrounding area

(6) type (cell cluster or single cell), etc.

We will consult with pathologists to ensure proper use of feature vector for correct diagnosis of diseases. Feature vector in mathematical form can be written as: x=[x1, x2, ..., xn].

Classifier Design

Classifier design is a process of obtaining classification rules via priori knowledge. One of the classifier design methods is an iterative process called supervised learning. A set of typical samples will be selected as the training set, coefficients of decision functions are iteratively adjusted to minimize probability of classification error. After the classifier is obtained, a set of test samples will be used to perform a confidence test and ensure that the classifier is accurate enough for the purpose of medical diagnosis. In order to achieve high diagnosis accuracy, classifiers must be application dependent, i.e., we must develop specific classifiers for each group or subgroup of pathology images with similar characteristics of samples. For example, different pattern recognition classifiers may be used for cytology images and histology images. Obviously, there is a trade off between diagnosis accuracy and the number of different classifiers to be used.

Classes may also overlap, which depends on the discriminative of the feature elements. For some undetermined cases, the computer should not make the final decision alone. Any diagnosis for ambiguous pathology images should be made manually with the help of pathologists.

In the following, we discuss some possible approaches for pathology pattern recognition.

1. Deterministic Approach

The Deterministic approach is a commonly used method where decision functions are used to determine the classification of a sample. Decision functions are a set of functions whose combined outputs will decide the membership of a particular input feature vector. Classifier design, in other words, is a process to find an optimal set of decision functions. Decision functions can be linear, quadratic or polynomial. Linear decision functions should be good for medical diagnosis since most of the pattern recognition (PR) algorithms converge for linear problems. Two classes are linearly separable if there exists a hyper plane which separates them accurately. The mathematical form of the linear decision function is:

d(x)=w(1)*x(1)+w(2)*x(2)+...+w(n)*x(n)+w(n+1),

where $n$is the dimension of the feature space,

W represents the weight space and X is the feature vector.

The goal of classifier design is to find W in the weight space which satisfies the specified optimality criterion.

2. Potential Pattern Recognition

Potential Pattern Recognition is a probabilistic effort in decision making based on the analysis of multiple variables, which shows great flexibility in manipulation and in the interpretation of data and patterns. Spscht (1967) applied a special form of potential function methods, called the polynomial discriminate method, to the diagnosis of heart diseases on the basis of vector cardiography. Noteworthy is the fact that a large percentage of the abnormal patients, as classified by the method, were only sub clinical and verified as abnormal only after subsequent tests. Willmes et al. (1980) suggests that, on a clinical basis, the potential method performs better than their cluster analysis method. Based on the fact that potential PR can use

both continuous and discrete multiple variables (and some successful reports of other researchers), we believe that this approach is worth investigating and we will access its effectiveness for pathology images.

3. Neural Network

A neural network is a massively parallel distributed processor that has a propensity for storing experimental knowledge and making it available for use. One of many examples of the application of neural networks to medicine was developed by Anderson et al. in the mid-1980s. It has been called Instant Physician. The idea behind this application is to train an auto associative memory neural network to store a large number of medical records, each of which includes information on symptoms, diagnosis, and treatment for a particular case. After training, the net can be presented with input consisting of a set of symptoms; it will then find the full stored pattern that represents the best diagnosis and treatment. The net performs surprisingly well, given its simple structure.

A neural network has two important properties: (1) its knowledge is acquired by the network through a learning process and (2) inter-neuron connection strength known as synaptic weights are used to store knowledge. As we know, medical knowledge is also accumulated or updated as physicians learn more and more about the human body. A neural network is good for medical applications because it resembles the human (physician) brain in its structure and functionality. It is relatively easy to update the knowledge stored in neural networks. By using a multiple layer structure of neural networks, it is convenient to implement a multistage classifier system for our application.

A neural net can use massively parallel nets composed of many computational elements connected by links with variable weights. Therefore, it is easier for neural networks to achieve a high computation rate which is essential for real time control in tememedicine applications. In addition, neural nets typically provide better robustness or fault tolerance. It is also able to adapt connection weights (continue learning) in real time. So, neural nets appear to be the best candidate for our application.

Conclusion

We surveyed different applications of pattern recognition in medicine. It was found that pattern recognition for radiology images is well developed while no significant research has been done in the area of pattern recognition of pathology images. Focusing on pathology images, we described the processes of data acquisition and feature extraction. Several ordinary pattern recognition approaches (deterministic approach, potential pattern recognition and neural network approach), are discussed for their implementation to medical images. We conclude that neural networks are the most promising approach for pathology image pattern recognition.

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5.5.3 Description for Edge Detection Program

Processing Steps:

- Blur the original image for subsequent image processing.
- Detect Edge: calculate the difference of pixel values between each pixel and its surrounding pixels. If the difference is larger than a user specified value, that pixel will be marked as 'edged pixel'. All edged pixels will form an 'edged image'.
- Skeletonize Edged Image: reduce the edged image to skeleton form (skeletonized image). This process is done by marking some unnecessarily edged pixels as 'non-edged pixels' – making edges thinner.
- Extract isolated objects from the skeletonized image. Each object is formed by edged pixels which are connected together. Extracted objects can be used for pattern recognition.

User's Guide:

The program name of the source code is *edge.c*, which is written in C and stored in directory */home/A6F/jguo/pr*. A demo image file *demo.ras* is also stored in the same directory. Currently, only raster image files are supported and the size of an image is hard coded as 450x300 pixels.

Necessary Resources :

The host machine must have X lib running and the resulting images must be displayed on a X terminal with a color depth of 8 bits. A Unix C compiler is needed to compile the source code.

Program Compilation

In order to compile this edge detection program, X lib and C standard header files are needed. Different computer hosts may have X lib and C standard header files installed in different directories. When compiling this program, you may need to change the make file and command to compile this program. For example, in order to compile the program in NPAC Sun workstation *nova*, you may type at command line:

```
cc -g edge.c -o edge -L/usr/local/X11/lib -I/usr/local/X11/include -lX11
-lm
```

Program Execution

To start the edge detection program, input this command line: `edge image.ras edge_percent`. *Image.ras* is a raster image file name of size 450x300, and *edge_percent* is a integer number between 0 and 100 which specifies the percentage of pixels in the image which will be marked as edge pixels. For example, you may type in the command line: `edge demo.ras 20` to run the program. Image *demo.ras* will be used for edge detection and 20 percent of the image pixels will be marked as edged pixels.

After the program is started, the original image will be displayed on the screen. When the program stops, hit the key 'c' to continue. Then the original image will be blurred and edge detection will be performed and displayed. At the next cursor prompt, type 'c' again and the edged image will be skeletonized and displayed.

Finally, individual isolated objects will be extracted from the skeletonized image and displayed on the screen one by one. Objects smaller than a specified size (width and height) will be treated as 'noise' and will not be displayed on the screen.

5.6 Telemedicine Conference

We prepared the following demonstrations for the Telemedicine Conference: Reality and Virtual Reality "Hospital of the Future" - Syracuse, OnCenter, 23-26 April 1995:

- Videoconferencing - delivery of high resolution pathology related images and movies via ATM and ISDN connections. We used InPerson on an SGI for a demonstration of videoconferencing software [Appendix D, Figure 14].

- Computer-based Patient Record - patient related data (texts, images, movies, audio/text annotations) stored in the Oracle database available via ATM/ethernet. Integration of the Database Server into the Web technology [Appendix D, Figure 15].

- Wavelet (lossy) compression technology applied to pathology images, paintings and photos with compression ratios as high as 150:1 [Appendix D, Figure 12].

- Video-on-demand - 22 medical movies available via ATM network [Appendix D, Figure 16].
- Image Processing - AVS, Khoros, 3DVIEWNIX.
- SGI based acquisition workstation (Olympus AX70 microscope, Kodak 420c camera, Sony CCD camera, image capture interface (tiff, rgb)).

During the conference, we experienced an extremely slow connection between the SGI Challenge in NPAC and the SGI Indy installed in the OnCenter. In one direction, we had an average speed of 23 KB/s ; in the other, the transfer speed was 3750 KB/s (B=byte). This very poor and assymetric performance was caused by incorrect values of tcp_sendspace and tcp_recvspace parameters in the SGI kernel on the Indy. By default, these parameters are equal to 60K. When we use the GIA 100 ATM adapter, the values of these parameters should be lowered to 16K.

We also prepared 6 posters for the telemedicine conference:

- Collaboratory and Telecommunications Experiments
- NPAC Facilities
- Image Processing Software
- ISDN and ATM Networking
- Telemedicine Database Management
- Image Compression Techniques for Telepathology

5.7 Final Demonstration

The final telemedicine demonstration was held at Rome Laboratory, Griffiss Air Force Base, on September, 12, 1995. During the demonstration, we presented the functionality of the Distributed Pathology Workstation built on top of the following hardware and software:

- Rome Laboratory, Rome
  - SGI Indy + Irix 5.3
  - GIA 100 ATM adapter + ForeThought Irix53_3.0.1b_1.28
  - Fore Systems ASX 200 ATM switch
  - InPerson 2.0 Videoconferencing Software
  - WebFORCE to Author/Serve
- SUNY HSC, Syracuse
  - SGI Indy + Irix 5.3
  - GIA 100 ATM adapter + ForeThought Irix53_3.0.1b_1.28
  - Fore Systems ASX 200 ATM switch
  - InPerson 2.0 Videoconferencing Software
  - WebFORCE to Author/Serve
  - Image Capture Software
  - Olympus AX70 Microscope
  - Kodak DCS 420c camera (SCSI interface)
  - Sony CCD - SSC -S20 camera (s-video)
- NPAC, Syracuse University
  - IBM Power Station with AIX/6000 v 3.2 - 128.230.3.70
  - Oracle 7.0 RDBMS
  - Web server httpd 1.4
  - SGI Challenge with IRIX 5.3 - 166.101.20.17
  - VMA 200 ATM adapter + ForeThought Irix53_3.0.1b_1.28
  - Web server httpd 1.3
  - AccuPress wavelet compressor

- Network
  - Asynchronous Transfer Mode
  - NYNET

List of demonstrations

- InPerson desktop videoconference over ATM network between Rome Laboratory and SUNY Health Science Center. InPerson is a multimedia desktop conferencing tool for SGI workstations such as the Indy, Indigo and Indigo2. Each conference included audio and either video or a static image of the participant. Use of the shared whiteboard and shared shelf is optional on a per-conference basis. The InPerson 2.0 desktop videoconferencing software was installed on an SGI Indy workstations in RL and SUNY HSC. The videoconference was running between RL and HSC over the ATM network. The functionality of the software was presented in comparison with other packages like Communique (Sun, SGI) or ProShare.

- Transfer of high-resolution images (whiteboard and shelf options). We have scanned and digitized 70 pathology images. The transfer of high quality images were demonstrated using InPerson videoconferencing software (whiteboard/shelf), Web and Web-Oracle technologies. The InPerson transfer is based on the file icon dragging/dropping scheme. Files placed on the shelf are instantly accessible to all persons in the conference. These images available on SGI at Rome Laboratory were transfered to the Oracle database.

- Local and remote acquisition of images from microscope. The acquisition station consited of an Olympus AX70 microscope, Kodak DCS 420c camera (SCSI interface, resolution 1572x1012), Sony CCD-SSC-S20 camera (s-video) and SGI Indy workstation with high-resolution monitor connected to the ATM network. The acquisition station was installed in SUNY HSC and allowed for local and remote capture of images from the microscope.

- Telemedicine database management - Web-Oracle gateway. We have installed a Web-Oracle interface which allows users to browse and modify the contents of the database by using Web technology. We demonstrated the following developments:
  - NPAC implementation of the Web-Oracle interface. The Oracle 7.0 server is running on IBM Power Station in NPAC and is available to Web Clients
  - Patient Record Database - the contents of the database have been prepared in cooperation with Dr. Corona from Suny HSC. Web-Oracle gateway permits connectivity between a medical database and the full power and scope of the Internet.
  - Interface which allows storing, disseminating and browsing of multimedia information in the Oracle database.
- Image compression techniques - wavelet compression.

  A. We demonstrated a Motif-based Graphical User Interface for flexible display of several pathology images on the screen allowing comparison of wavelet and JPEG compressed images with the original image. B. Competition demo - implemented as a set of CGI scripts - demonstrated the excellent quality of wavelet compression technology. This demo is built around AccuPress for Multimedia commercial software from AWARE Inc. It supports 8-bit gray scale and 24 bit color imges in raw and TIFF formats. The compression ratio can be varied over a wide range (6:1 - 150:1,for 24 bit TIFF).
- Image processiong - 3D reconstruction.

  A. We demonstrated 3dviewnix - a transportable, very inexpensive software system developed by the Medical Image Processing Group, Department of Radiology, University of Pennsylvania, Philadelphia. It has state-of-the-art capabilities for visualizing, manipulating, and analyzing multidimensional, multimodality image information. It is designed to run on Unix machines under X-windows. It uses a data protocol that is a multidimensional generalization of the ACR-NEMA standards. It has been installed and tested on Sun work-

stations in NPAC
B. 3DBrain - built in NPAC for 3D reconstruction of serial sectins. The software was tested on the Visible Human MRI head data.

- Project Information Server designed for delivery of documents and data related to the project. It is available for Internet and NYNET users (**http://kopernik.npac.syr.edu:1200 or http://128.230.117.17:1200**). The server is installed on an SGI Challenge (NPAC) and is available via FDDI and Ethernet interface. The server contains many medical images stored in TIFF, GIF or JPEG formats, as well as medical clips in MPEG format.

Appendix A. Desktop Collaboration Tutorial

by G.C.Fox and R.Markowski

Desktop collaboration vs face-to-face meeting

- Nowadays business is conducted on a long-distance basis
- Telephone, fax and e-mail do not give a face-to-face contact
- NY - San Francisco roundtrip travel – $1500
- Intel ProShare setup – $6000

Collaborative environment

- Each work situation has its own set of tools and social conventions . Collaborative environment must be adaptable for use in each of these situations
  - `Staff meetings, project meetings`
  - `Engineering teams, formal presentations`
  - `Medical consultations, military briefings`

Requirements for Collaborative Environments

- Create customized collaborative environment (user interface) with the appropriate access and membership policies
- Add collaborative features to specialized applications
- Incorporate distributed multimedia functions
- Exploit the latest state-of-the-art audio, video and network technologies
- Develop products to run over cross-platform and multiple network technologies
- Enable open collaborative applications (sharing documents, images)
- Set of separate modules (audio, video, whiteboard,...)

Common collaborative tools

- Real-time video and audio capture, display and synchronization
- Audio and video compression and decompression
- Video and audio network data stream management
- Tools Provided to User in Typical System
  - `Audio Conferencing Tool`
  - `Text Tool with direct Input and File Manager selection`
  - `Shared Write Board for text-only conferencing (cf. forum on Internet)`
  - `Shared White Board allows text and Images to be written by anyone in common area`
  - `Graphics Tool allows Image exchange`
  - `Video to Image capture and sharing`
  - `Shared video including video of site participants`
  - `File exchange tool`
  - `Shared Application Tool -- One application sends output to multiple sites`

Audio Tool Functionality

- Audio Conferencing allows everyone in the conference to talk to each other
- Hardware requirements: Microphone, speaker or headphones
- Control Panel Functionality
  - `Sending/playback volume Control; mute button`
  - `Local Monitor volume`
  - `Audio Compression (PCM, ADPCM, G.711, G721 etc.)`

- `Sampling (8,16,32,44.1,48 Khz)`
- `Output Device (Speakers, Headphones)`
- `Audio/Video Synchronization`
- `Echo Cancellation -- The placement and sensitivity of the microphone can cause audio from the speaker to be picked up and rebroadcast back to the conference`
- `Silence sensor -- defines a minimum audio level`

Text Tool Functionality

- Allows one to incorporate and distribute notes and text to the conference members
  - `Received notes can be saved on disk`
  - `Text can be dragged / gotten from File Manager or typed directly`
- Shared Write Board
  - `Tool for text-only conferencing. Allows one to carry on a text based conversation with all participants using just the keyboard`
  - `The entire transcript can be saved and scrolled etc.`
  - `Messages which appear in the public window can be sent anonymously or can identify the author`

Graphics Tool Requirements

- Allow one to capture and send still images to other conference participants
- The incoming graphics can be saved, windowed, deleted.
- Useful for displaying charts, graphs and images
- Snapshot from a given screen can be sent to other members of collaboratory
- Previously stored images can be loaded and sent via Graphics Tool

Shared White Board Functionality

- A virtual drawing board shared by all members of the conference
- Allow users to simultaneously markup and edit a virtual whiteboard
- Whiteboard is automatically shared with the other participants
- The contents (entire or selected region) of the Whiteboard can be saved, printed and cleaned.
- Functionality
  - A pointer(mouse) can be seen by all participants as one member moves over screen
  - Drawing: Freestyle lines, Straight lines, rectangles, ellipses, squares and circles with various fill options as in say Aldus Freehand.
  - Move and copy selected objects
  - Eraser
  - Color and line width choice
  - Color and font of text can be chosen
  - Graphics files can be loaded from disk or dragged/dropped from File Manager
  - QuickPic utility allows snapping of images from the whiteboard and
    other parts of screen

Video to Image Tool Functionality

- Used to access video and create images from any source including analog or digital camera and VCR.

- Requires a video capture board
- (we use for TV Tool and Video to Image Tool (under Communique!) the Parallax board on SUN for video capture and JPEG compression)
- Image size should be controllable
- A single frame should be selectable from video and treated by Whiteboard or Graphics tools

TV Tool Functionality

- Video can be sent from any source (including camcorder monitoring participants at one site) to other conference participants
- Requires video camera and/or VCR and video capture board
- Control Panel
  - `Select who will receive video`
  - `Start and Stop Video Transmission`
  - `Control frame rate (typically 15 frames per second)`
  - `Set compression method (motion JPEG, MPEG, CellB etc.)`
  - `Compression ratio (quality) control`
  - `Video Image size control`
  - `Brightness, color, contrast control`
  - `Bandwidth monitor for sharing between conferencing capabilities`

File Exchange Tool Functionality

- Allow one to send files to selected conference participants
- Allow one to receive files from the other participants
- Files can be saved or deleted

Share Application Tool Functionality

- Allow conference members to share an application window and application acts as though it is running locally
- All members can simultaneously participate in editing a CAD drawing or making changes to a spreadsheet
- No limitation of significance in shared application type
- Sharing applications that do not open their own window (e.g. C Compiler) requires a terminal application (xterm)

Video Compression

- MPEG - Motion Picture Experts Group; lossy algorithm;
  - `standard for compression synchronized audio and video; full screen,`
  - `30 fps playback at 352x240 resolution`
- H.261 - similar but not compatible with MPEG; videocodec for audiovisual services at px64 Kbps (p=1..30);
  - `describes videosource coder, video multiplex coder and the transmission coder;`
  - `video for ISDN`
- CellB - lossy algorithm, intra-frame compression; very efficient to decode in software;
  - `motion sensitive compression scheme (compresses across frames); SunVideo Board`
- Indeo - Intel lossy compression;
  - `Currently 15 fps, 320x240;`

- `Indeo 4.0 full-screen 30 fps on 90MHz Pentium`

- InSoft DVE 1- intraframe algorithm; InSoft's proprietary; very efficient to decode quickly in software; VideoPix or RasterOP cards
- Motion JPEG - higher quality than CellB;
  - `lossy algorithm; we can control balance between compression and quality; very complex - difficult and time consuming to decode in software; Parallax Card`
- Other: HDCC, H.221, H.242, QuickTime, Cinepak, TrueMotion-S

Audio Compression

- PCM - Pulse Code Modulation
- ADPCM - Adaptive Differential PCM
- G.711 - PCM for voice frequencies; 64 Kbps, 8KHz PCM audio encoding
- G.721 - 32 Kbps, ADPCM audio encoding
- G.722 - 7 KHz audio encoding with 64 Kbps
- Other: a-law, G.725
- More details about audio/video compression can be found in: **ftp://rtfm.mit.edu/pub/usenet/news.answers/compression-faq**

Open DVE - Digital Video Everywhere (Insoft, Inc.)

- Open architecture
- API and Toolkit - programming interface to create distributed multimedia and collaborative applications

- Open DVE API (LibraryAPI) - ability to write a single application without concern to the underlying workstation or network technology
- Open DVE Toolkit - common set of plug-ins: audio toolkit, video toolkit, TV toolkit, whiteboard, writeboard, share application tool
- Conference Engine and plug-ins (clients)
- Creation of modified and new collaborative applications

Communique! **InSoft** ($9495)

- Sun IPX, Parallax XVideo SBus 24 SVC, SunOS 4.1.3, OpenWindows 3.0, SBA200
  - `Sun ws (SunOS 4.1.3 or Solaris 2.3; OpenWindows 3.0 and Motif 1.1)`
  - `IBM RS/6000, HP 9000/700, DEC Alpha (AIX, HPUX, DEC OSF)`
  - `PC and SGI scheduled for 1995 (MS Windows, IRIX)`
- Digital Video Everywhere (DVE) - open system platform
- TCP/IP over ATM, ethernet, FDDI, FR, ISDN, SMDS, Switched 56
- Functionality
  - `virtual conference room`
  - `audio tool (echo cancellation, audio/video synchronization)`
  - `text tool, shared write tool`
  - `graphics tool, shared whiteboard`
  - `TV tool, Video tool (JPEG, MPEG, CellB, Indeo)`
  - `file exchange tool`
  - `SHARE application tool`

- multipoint
- NPAC Performance tests December 1994
  - Shared whiteboard and Graphics tool
    - *image.ras (305KB): ATM - 25sec; Eth - 23sec*
  - Video tool
    - *full window (640x480): ATM - 25sec; Eth - 15sec*
    - *1/4 window (320x240): ATM - 8 sec; Eth - 6 sec*
  - TV tool
    - *full window: ATM - 10.1 fps; Eth - 10.8 fps*
    - *1/4 window: ATM - 15.0 fps; Eth - 15.9 fps*
  - Audio - better over ATM (sampling rate 8KHz)
  - SHARE : can launch only one application; no form of access control
  - Note SHARE allows one to launch X applications (xv,xterm, Mosaic ...) and share your version with other conference participants who for instance see the same Mosaic spawned hyperlinks.
- Note Communique! currently runs better on Ethernet than ATM!
- Message Packet Size MTU: ethernet=1500; FDDI=4532; ATM=9188 is conventional (use netstat -i)
- MTU cannot be redefined in Communique! which is hard wired in optimization to Ethernet. InPerson allows one to change value of MTU
- tcp_sendspace/ udp_sendspace/ tcp_recvspace/ udp_recvspace are UNIX kernel parameters which define TCP/IP actions. The buffer sizes (16K for sendspace) is too low for ATM and when increased to 60K one sees a performance boost of a factor of two for ATM.
- Audio compression

- PCM, ADPCM, G.711, G.722, a-law

- Video compression depends on the type of video capture board
  - motion JPEG (Parallax), CellB (SunVideo board), DVE1 (VideoPix card)
  - new version (Communique! 4.0) also supports: Indeo, H.261
- New version will support H.320

InPerson ver 2.0 SGI ($495)

- SGI Indy/Indigo; IRIX 5.3, GIA 100
- Multicast routing and tunneling for multiway conferences
- License required
- Ethernet, ATM; ISDN/PPP, T1, High Speed LAN
- Functionality
  - audio (def 16KHz, max 48 KHz, echo cancellation, Intel DVI compression, consumes 64Kbps, supports H.320)
  - video (default 15fps, max 20fps, 160x120, 208x156, 320x240, HDCC compression)
  - shared whiteboard (multipage)
    * 3D models can be imported and shared
    * Images transmitted using RLE compression
  - file exchange (shelf) - based on the file icon dragging/dropping
  - no SHARE application
  - multipoint (up to 6)
  - customization (control panels)

- phonebook server

- Video compression
  - `HDCC, H.261, uncompressed (in software)`
- Audio compression
  - `G.728 + echo cancellation (Acceleration board required)`

ProShare ver 1.8 Intel ($2499)

- NPAC implementation on Compaq Deskpro XL 566 (Pentium 66MHz, 16 MB RAM, 529 megabytes HDD, video resolution 800x600, EISA bus, CD ROM), MS Windows 3.1
- Transport ISDN 2B+D or LAN
- Functionality
  - `dial list`
  - `audio (external speakers, mute, microphone and earphone in headset)`
  - `video (resize, snapshot, camera control, zoom in/out)`
  - `10-15 fps, icon, 160x120, 320x240`
  - `shared application`
  - `shared notebook (multiple pages)`
- Only point-to-point
- Control panels (general, audio, video, dial list)

Eclipse Videoconferencing System

- Compression Labs, Inc. California
- Video

- `input/output: main camera, document camera, monitor, VCR`
- `compression CTX (CLI Proprietary), QCIF (CCITT standard)`
- `resolution: 256x240 (CTX), 176x144 (QCIF)`
- `picture-in-picture (PIP) movable, 1/9th screen`

- Audio
  - `echo cancellation`
  - `full duplex`
  - `compression: G.711 (56kbps), G.728 (16kbps)`
  - `input: main microphone, aux microphone, VCR`
  - `output: monitor, VCR`
- multipoint compatibility: H.320, H.231
- transmission
  - `network interface: RS-449, V.35, dual DSU (switched 56) or ISDN BRI`
  - `data rate: 56, 64, 112, 128 kbps`
  - `standards: framing H.221, call setup H.242`

MBONE - Multicast Backbone

- Virtual network - uses a network of special (up and coming) routers that support multicast
- One-to-many and many-to-many network delivery services for applications such as videoconferencing and audio where several hosts need to communicate simultaneously
- Teleconferencing can be done in the world of Internet (variable packet delivery delays, bandwidth limited)

- IP multicast addressing (RFC 1112), IP Class D, 224.0.0.0-239.255.255.255
- Sun - multicast (modified kernel), SGI mrouted, dedicated routers
- Audio -frequent dropouts
- Video - 1-4 fps over Internet
- Topology: star and mesh - islands linked by virtual point-to-point tunnels
- Tunneling - encapsulating the multicast packets inside regular IP packets – allows multi-casting (multiple addresses for same packet with broadcast as an example where ALL get message). Most routers do not support multicasting and so must hide special multicast packet in conventional packet where insides are exposed by the special routers
  - `Multicasting can dramatically reduce network use if used well as if N recipients, only need 1 not N packets on trunk lines.`
- TTL - time-to-live - field in a packet , decremented each time the packet passes through a router (prevent network links saturation)
- Protocols: IGMP (Internet Group Management Protocol), DVMRP (Distance Vector Multicast Routing Protocol), RTP (Real Time Protocol over TCP/IP)
- A new site announces itself to the MBONE mail list, and the nearest providers decide who can establish the most logical connection path
- Compression: JPEG, H.261, Wavelet-based encoding, PCM (audio)
- Application tools (Sun, SGI, HP, DEC)
  - `SD - Session Directory - session availability is dynamically announced`
  - `NV - Net Video (Xerox Palo Alto)`
  - `WB - Whiteboard (Lawrence Berkeley Lab)`

- VAT - Visual Audio Tool (Lawrence Berkeley Lab)
  - IMM - Image Multicaster Client
  - NEVOT - Network Voice Terminal
  - MMCC - Multimedia Conference Control Program

- Bandwidth capacities lower than T1 are generally unsuitable for MBONE video
- All Public Domain!

MBONE References

- ftp://venera.isi.edu/mbone/faq.txt
- ftp://parcftp.xerox.com/pub/
- net-research/mbone-map-big.ps
- http://www.research.att.com/
- mbone-faq.html
- http://www.eit.com/techinfo/
- mbone/mbone.html

Introduction to Collaborative MOO Environments

- MOO's stand for Object Oriented MUD's where
- MUD stands for Multi-User Dungeons or if one is trying to be high class Multi-User Dimensions
- These are virtual-reality or more precisely virtual-community systems
- The goal is to set up a computer environment which resembles more or less faithfully the real world.

- `MOO's and MUD's involve people, places and things`

- MOO's are a modern object oriented implementation of the older MUD's and are developed at XEROX PARC in Palo Alto
- Some URLs:
  - http://www.ccs.neu.edu/home/fox/moo/www.html - MOOs that have WWW gateways
  - http://www.maths.tcd.ie/pub/mud/moo-www/directory.html - MOO-WWW
  - http://www.ccs.neu.edu/home/fox/moo/ - MOO-Cows FAQ
  - http://draco.centerline.com:8080/~fraul/mud.html

A Formal Definition of Collaborative MOO Environments

- A MOO ..is a network-accessible, multi-user, programmable, interactive system well-suited to the construction of text-based adventure games, conferencing systems, and other collaborative software. Its most common use, however, is as a multi-participant, low-bandwidth virtual reality...- excerpted from the _LambdaMOO Programmer's Manual_, version 1.7.6, written by Pavel Curtis.
- MOO's are like Dungeons and Dragons or Computer role playing games such as Zork series
- Rather perversely, they use a fundamental spatial model but are entirely (but elegantly) text based
- Many – such as Argonne – are researching addition of visual material with animation of people and environment.
  - `This would become the model where client videogames dial central servers which create a fully realistic 3D world in which tanks, F16's and explorers of videogame interact with each other`
  - `MOO's stress the acquistion of knowledge and not the destruction of other players`

Characteristics and Use of a MOO

- MOOs are composed of three types of elements: People, places, and things. Because one of the goals of a MOO is to resemble (within the limitations of the medium) reality, MOOs have many of the things that one would see in everyday life: cars and houses, people and refrigerators, pets and so forth. The people who inhabit MOOs attempt to add as much detail to the MOO as possible. This means adding details as simple as making a character able to smile or as complex as establishing a democratic system by which the MOO is governed (such as the one that exists at LambdaMOO).
- FTP from parcftp.xerox.com as pub/MOO/contrib/TinyMUD will compare MUD's and MOO's
- To try out a MOO, do (march 27 1995)
  - `telnet io.syr.edu 1234 (ASKEric MOO)`
  - `telnet arthur.rutgers.edu 8888 (English as a Second Language MOO)`
- Type connect guest to join MOO (temporarily)
- Then you type in the name you want to use. It will ask you to verify this (type yes) and give yourself a description.
- To find out who is currently logged on and where they are, type
  - `@who`
- To talk to anyone in a place different from where you are, type
- page <player> <message>
  - `(such as: page Colega Hi! May I join you? )`

Interacting in a MOO

- To join anyone currently logged into the MOO, type
  - `@join <player> (such as: @join Colega)`
- Once you are with someone in a room, you can talk to them using just one quotation mark at the beginning of your sentence
- To show actions and emotions, type the colon (:) followed by a sentence with no subject in the third person singular. So if Lonnie types
  - `:smiles and waves to everybody.`
- Everyone in the room will see
  - `Colega smiles and waves to everybody.`
- To access help files, just type help and follow instructions
- To leave, type @quit

A MOO Seesion Starts Like This

- *** Connected ***
- Reception Area
- This is a large, open and airy room that is modern and appealing. An information booth can be seen off to one side, and a number of people are walking about silently from place to place. You seem to have found yourself in a learning and conference center, and this is the reception area. The room narrows into a hallway to the south, and just over the hallway exit is a large clock that hangs beneath a large metallic sign reading: Welcome to AskEricMOO.
- The clock on the wall reads: 4:21pm.
- Nobody is sitting at their desks.

MOO Commands from request: help manipulation

- Objects usually have verbs defined on them that allow players to manipulate and use them in various ways. Standard ones are:
  - `get -- pick an object up and place it in your inventory`
  - `drop -- remove an object from your inventory and place it in the room`
  - `put -- take an object from your inventory and place it in a container`
  - `give -- hand an object to some other player`
  - `look -- see what an object looks like`
- You can see what objects you're carrying with the 'inventory' command; see 'help inventory' for details.
- Some specialized objects will have other commands. The programmer of the object will usually provide some way for you to find out what the commands are. One way that works for most objects is the 'examine' command; see 'help examine' for details.
- The following specialized objects have help entries you should consult:
  - `notes -- objects that allow text to be written on them and read later`
  - `letters-- notes that a recipient can burn after reading`
  - `containers -- objects that may contain other objects`

Appendix B. Compression Technology Tutorial

by G.C.Fox and R.Markowski

Abstract

- This section describes image and video compression schemes concentrating on Wavelets which seem most powerful although JPEG and MPEG using related but less efficient Fourier technology will be used much more widely initially
- Wavelets are described in detail for Image case where they are discussed for Telemedicine application
- JPEG JBIG Fractal H.261 Schemes are briefly reviewed
- The contents of this section are presented as
  - CPS616 Module on Compression, March 4, 1995
  - REU seminar: Compressing Still and Moving Images, June 1995
  - HPDC4 tutorial, Washington, August 1995

Compressing Still and Moving Images

- image 2000x2000x24 bpp = 12MB
- one second of NTSC-quality video requires 23 MB
- compression - eliminating redundant or less critical information
  - `Spatial redundancy: values of neighboring pixels are strongly correlated`
  - `Spectral redundancy: the spectral values for the same pixel location are correlated`
  - `temporal redundancy: frames show very little change in the sequence`

- decreases the time and cost of transmission and the requirements for storage

Image Compression

- lossless - removes the redundancy in the signal; ratio 3:1; the heights of every pixel are perfectly reproduced
- lossy - selectively discards less important information; ratio 100:1
- controversy: the critical feature of any lossy compression is what is important and what is not.
- evaluation of several image compression technologies
  - `JPEG - the leading standard in visual compression (compresses the image block by block), lossy, full color, block by block`
  - `JBIG - binary images, lossless, gray scale`
  - `Fractal - compression slow, decompression fast, lossy, 1000:1, bad quality`
  - `PhotoCD - Kodak, 96x64, 192x128, 384x256, 768x512, 1536x1024,3072x2048`
  - `Wavelet - discovered in 1987, lossy, ratio 100:1, compresses the image as a whole`

Huffman and Other Compression Techniques

- Huffman encoding; Shannon-Fano encoding; arithmetic encoding
  - `input is sliced into fixed units while the corresponding output comes in chunks of variable size`
- RLE -Run Length Encoding (TIFF, BMP)
  - `lossless: Replace up to 127 identical characters by two bytes`

    `--`

    `first byte is number of identical characters in string, second`

byte

is character itself

- For example: AAAAbbbbbccct ---> 4A5b3c1t

- LZW - Lepel-Ziv-Welch (TIFF, GIF)
  - Directory based encoding algorithm
  - compress, zoo, lha, pkzip. arj
  - LZ77, LZ78
  - input is divided into units of variable length (words) and coded in a fixed-length output code
  - shorter bit patterns for most common characters
- DCT - Discrete Cosine Transform (MPEG, JPEG, H.261)
  - lossy; converts the spatial image representation into a frequency map
  - DCT scheme is effective only for compressing continuous-tone images (from Graphics File Formats, O'Reilly and Associates Inc., page 162 in description of JPEG algorithm)

JPEG - Joint Photographic Experts Group

- current international standard for image compression
- lossy algorithm: the threshold of visible difference 20:1
- lossless compression mode: 2:1 ratio, 12bpp (bpp is bits per pixel)
- designed for compression of full-color (24 bit) or gray-scale digitized images of natural scenes (continuous tone)
- exploits the known limitations of the human eye (10,000 colors simultaneously)
- ratio can be varied

- DCT (Discrete Cosine Transformation) and Huffman coding
- source available (Independent JPEG Group)
- ftp://ftp.uu.net/graphics/jpeg/wallace.ps.Z

JPEG Algorithm Specification

- First transfer the image into a suitable color space (RGB -> Image representations which separate luminance and chrominance YUV, YCbCr, etc.); the human eye is not as sensitive to high-frequency color as it is to high-frequency luminance
  - YUV is used in European TV standards and corresponds to YIQ in American NTSC. Y specifies gray-scale or luminance; U and V the chrominance
  - YCbCr is another color space where again Y is component of luminancy but Cb and Cr are respectively ther color components in
    blue(Cb) and red(Cr)
- the luminance component is left at full resolution; color is usually reduced 2:1 (2v1h,2v2h)
  - This means chrominance reduced 2:1 vertically wiuth no horizontal reduction(2v1h) or reduced both horizontally and vertically (2v2h)
- Then group the pixels for each component into 8x8 blocks; transform each block through DCT
  - Note for later -- need blocks as natural frequencies varies over image and not constant on a line of pixels as would correspond to
    Fourier transforms over full x or y of image. Wavelets naturally chooses block size. JPEG has fixed blocks

- In each block, divide each of the 64 frequency components by a separate quantization coefficient and round to integers; fundamental lossy step
- Encode the reduced coefficients using Huffman or arithmetic coding (license)
- Add headers and output the result

JBIG - Joint-bi-level Image Experts Group

- Losslessly compresses binary images (one bit/pixel)
- Effective for bi-level images (black and white)
- Extended to gray scales with up to 8 bits per pixel with good results up to 6 bits per pixel
- Based on IBM's Q-coder - patented technology (no source)

Fractal Compression

- lossy algorithm
- patented technology by Barnsley (no source)
- compression extremely slow (many hours)
- decompression fast
- theoretically very high ratio - 1000:1
- based on Iterated Function Theory and Partitioned Iterated Function Theory
- for compression ratio up to 40:1 JPEG is better; quality worse than wavelets or JPEG
- details are generated when zooming in the advanced form of interpolation
- Birth of fractal geometry in paper by B.Mandelbrot, the Fractal Geometry of Nature, 1977

- J. Hutchinson: Iterated Function Theory, 1981
- M.Barnsley, Fractals Everywhere, 1988
- in the forward direction fractal mathematics is good for generating natural looking images (trees, clouds, mountains)
  - `Used in Computer Graphics (Fractal trees,Mountains etc.)`
- in reverse direction can be used to compress images
- inverse problem: to go from a given image to Iterated Function System that can generate the original (unsolved)
- there are not many fractal compression programs available
- the fractals that lurk within fractal image compression are not those of the complex plane (Mandelbrot, Julia), but of Iterated Function Theory
- example: Sierpinski's Triangle

MPEG - Moving Picture Experts Group

- standard for compression (synchronized) audio and video
- 4 parts: video encoding, audio encoding, systems (synchronization) and compliance testing
- defines 352x240 pixels (30 fps in USA, 25fps in Europe)
- MPEG-1- designed for bandwidth up to 1.5 Mbps
- MPEG-2 - higher quality; designed for bandwidth 4-10 Mbps
- MPEG-3 - does no longer exist; MPEG-4 - very low bitrate coding
- DCT (Discrete Cosine Transform) done on 8x8 blocks
- lossy algorithm with compression in space (DCT) and time (frame to frame)

- 3 types of frames
  - `I (Intra) frames - sent every 10-12 frames as still images`
  - `P (Predicted) frames - deltas from the most recent I or P frame`
  - `B (Bidirectional) frames - interpolation between I and P frames`

H.261 - similar to but not compatible with MPEG

- CCITT standard
- VideoCodec for Audiovisual Services at px64 Kbps (p=1..30)
- describes videosource coder, video multiplex coder and the transmission coder
- designed for ISDN
- defines two picture formats: automatically build in block structure adaptively to get more detail where you need it.
  - `CIF (Common Intermedia Format) - 288x360 luminance, 144x180 chrominan ce`
  - `QCIF (Quarter CIF) - 144x180 of luminance and 72x90 of chrominance`

Introduction to Wavelets

- new technology
- signal analysis - weighted sum of basis functions
- Infinitely many possible sets of wavelets
- coefficients contain information about the signal
- basis functions
  - `impulse function reveals information only about the time domain behavior of the signal`

- Fourier representation reveals information about signal's frequency domain behavior
- we want to have representation which contains info about both the tim e and frequency (frequency content of the signal at the particular instant of time)

- Heisenberg inequality - resolution in time and in frequency cannot both b e made arbitrarily small
- Image: low frequency events are spread out in time and high frequency eve nts are localized in time
- sines or cosines (FFT) - cannot provide information about the time behavior of signal because they have infinite support
- impulse function - frequency behavior is not described because of its infinitesimally small support
- wavelets - set of basis functions each with finite support of a different width
- wide variety of wavelet-based image compression schemes reported in the literature

Discrete Wavelet Transform

- FFT vs DWT
  - Individual wavelet localizes pretty well in both time(space) and frquency
  - Fourier expansion functions localized very well in frequency but not all in space or time
- Both fast, linear operations; invertible and orthogonal
  Expansion Functions:

$$\Psi_{\mu k} = 2^{\frac{\mu}{2}} \Psi_{Mother}(2^{\mu} x - k) \tag{4}$$

Expansion of f(x):

$$f(x) = \sum_{\mu} \sum_{k} c_{\mu k} \Psi_{\mu k} \tag{5}$$

Coefficients in expansion of f(x):

$$G_{\mu k} = \int_{-\infty}^{\infty} f(x) \Psi_{\mu k}^{\pm} dx \tag{6}$$

Structure of Wavelet analysis

- Representation of general functions in terms of simpler, fixed building blocks
- Wavelets = small waves
- continuous wavelet transform:
  - `translation (b) and dilation (a) parameters vary continuously`
- or Discrete wavelet transform
- Multiresolution analysis

Wavelet Transform Characteristics

- decorrelates the pixel values of the image and concentrates the image info into a relatively small number of coefficients
- can be implemented as a pair of Quadrature Mirror Filters (QMF) which splits a signal's bandwidth in half
  - `lowpass or smoothing`
  - `filter (H)`
  - `highpass filter (G)`
  - `which expresses detail`

Mathematical Structure of Discrete Wavelet Transform-I

- Transform can be written for one of $log_2 N$ steps as a matrix operation. Each step deals with half of data from the previous step and resolution examined doubles at each step.
- In this way we look at ALL resolutions i.e. all length scales
- Each smoothing is constructed in this particular wavelet formulation as an average over 4 points

$$f_0 \rightarrow c_0 f_0 + c_1 f_1 + c_2 f_2 + c_3 f_3 \tag{7}$$

- The matrix is orthogonal if:

$$c_0^2 + c_1^2 + c_2^2 + c_3^2 = 1; c_2 c_0 + c_3 c_1 = 0 \tag{8}$$

- The matrix will be zero for the first two moments on sets of four points if:

$$c_3 - c_2 + c_1 - c_0 = 0; 0c_3 - c_2 + 2c_1 - 3c_0 = 0 \tag{9}$$

Mathematical Structure of Discrete Wavelet Transform-II

- The solution of these 4 equations is:

$$c_0 = (1+\sqrt{3})/(4\sqrt{2}); c_1 = (3+\sqrt{3})/(4\sqrt{2}) \tag{10}$$

$$c_2 = (3+\sqrt{3})/(4\sqrt{2}); c_3 = (1+\sqrt{3})/(4\sqrt{2}) \tag{11}$$

- The smoothing Filter H is the average:

$$c_0 f_0 + c_1 f_1 + c_2 f_2 + c_3 f_3 (= 1 if all f_i = 1) \tag{12}$$

- The detail is contained in operator G:

$$c_3 f_0 - c_2 f_1 + c_1 f_2 - c_0 f_3 (= 0 if all f_i = 1) \tag{13}$$

- First step produces N/2 smooth and N/2 detail values
  - Then we take N/2 smooth values and repeat step getting
  - N/4 smooth and N/4 further detail results at double spatial resolution
- This recursively leads to pyramid algorithm

How Image wavelet compression works

[Appendix D, Figure 17]

- We have reviewed 1D Wavelet Transform
- There are Three steps in 2D Image Case
  - `transformation of the image data using a predefined set of basis functions (multiresolution and orthogonal)`
  - `quantization of the basis function coefficients (lossy)`
  - `coding of the resulting data set to remove redundancy (Huffman lossless encoding)`

2D Forward/inverse wavelet transform

- Best methods use direct 2D methods starting with 2 by 2 or similar pixel blocks. However one can compose in several ways 1D transforms. It is NOT best to first transform in x and then transform in y. Rather ...
- A nice method uses two separate but INTERMIXED 1D transforms
  - **`Image filtered along the x dimension`**
  - **`Downsample by 2 along x`**
  - **`Filter along the y dimension`**
  - **`Downsample by 2 along y`**
- Recursively transform the average signal (depending on required ratio)

- We have matrix of coefficients (average signal and detail signals of each scale); no compression has been accomplished yet; in fact there has been an increase in amount of storage required

Wavelets – Quantization

- compression is achieved by quantizing and encoding coefficients
- coefficients that corresponds to smooth parts of data become small and can be set to 0
- we can eliminate (set to zero) these coefficients with small magnitudes without creating significant distortion in the reconstructed image
- energy invariance
  - `total amount of energy in the image does not change when the wavelet transform is applied`
  - `any change to wavelet coefficients will result in proportional changes in the pixel values of the reconstructed image`
- we can eliminate all but a few percent of wavelet coefficients
- Quantizing of non-zero wavelet coefficients
  - `many-to-one staircase functions`
  - `decision points {Di,i=0,...,n}`
  - `reconstruction levels {Ri,i=0,...,n}`
  - `input value 'x' is mapped to a reconstruction level 'Ri' if 'x' lies in the interval (Di, Di+1]`
  - `separate quantizer for each scale`

Wavelets – Coding

- codec = encoder/decoder
- losslessly compressing and decompressing the sparse matrix of quantized coefficients
- wide variety of schemes
- compromise between: memory, execution speed, available bandwidth, reconstructed image quality
- example: Shapiro's Zero Tree encoding

Wavelets in Telemedicine

- Massachusetts General Hospital: no clinically significant image degradation was identified in radiology images up to 30:1
- wavelet-based compression technology is superior to all other compression technologies (keeps details, high compression ratio)
- from a signal processing standpoint, one may view the image as a signal that has high-frequency (high-spatial detail) and low-frequency (smooth) components.The algorithm filters the signal and then iterates the process.

Wavelets -existing software

- HCOMPRESS - astronomical images, Richard L.White, Space Telescope Science Institute (gray scale)
- EPIC - Efficient Pyramid Image Coder, Eero P.Simoncelli, MIT Media Library
- IMAGER LIBRARY - available on the Web via the Wavelet Digest home page
- Commercially available software for medical applications; Aware, Inc - Accu-Press Library

Wavelets – Video compression

- exploiting the temporal redundancies present in an image sequence (as done by MPEG)
- techniques: hierarchical motion compression, 3D subband coding
- very time consuming - 256x256x8bpp image on 66MHz 80486 - 0.25 sec inverse wavelet transform of a single full frame (4 frames per second)
- it is necessary to perform the complete inverse transform for each frame (in a slowly varying image sequence)
- 16 frames per second if just transform changes in image – fewer nonzero pixels and so faster

Appendix C. Project Personnel

- Dr. Robert Corona - Physician Director of Telemedicine and Medical Informatics, SUNY Health Science Center
- Dr. Geoffrey C.Fox - Professor of Computer Science and Physics at Syracuse University, Director of Northeast Parallel Architectures Center
- Dr. Edward Lipson - Professor and Acting Chair, Department of Physics, Syracuse University, Faculty Associate of Northeast Parallel Architectures Center
- Dr. Roman Markowski - Researcher and Project Leader, NPAC Syracuse University
- Dr. Marek Podgorny - Associate Technical Director, NPAC and InfoMall
- Srividhya Narayanan - Graduate Assistant
- Murali Pawar - Graduate Assistant
- Jiangang Guo - Graduate Assistant

Appendix D. Figures

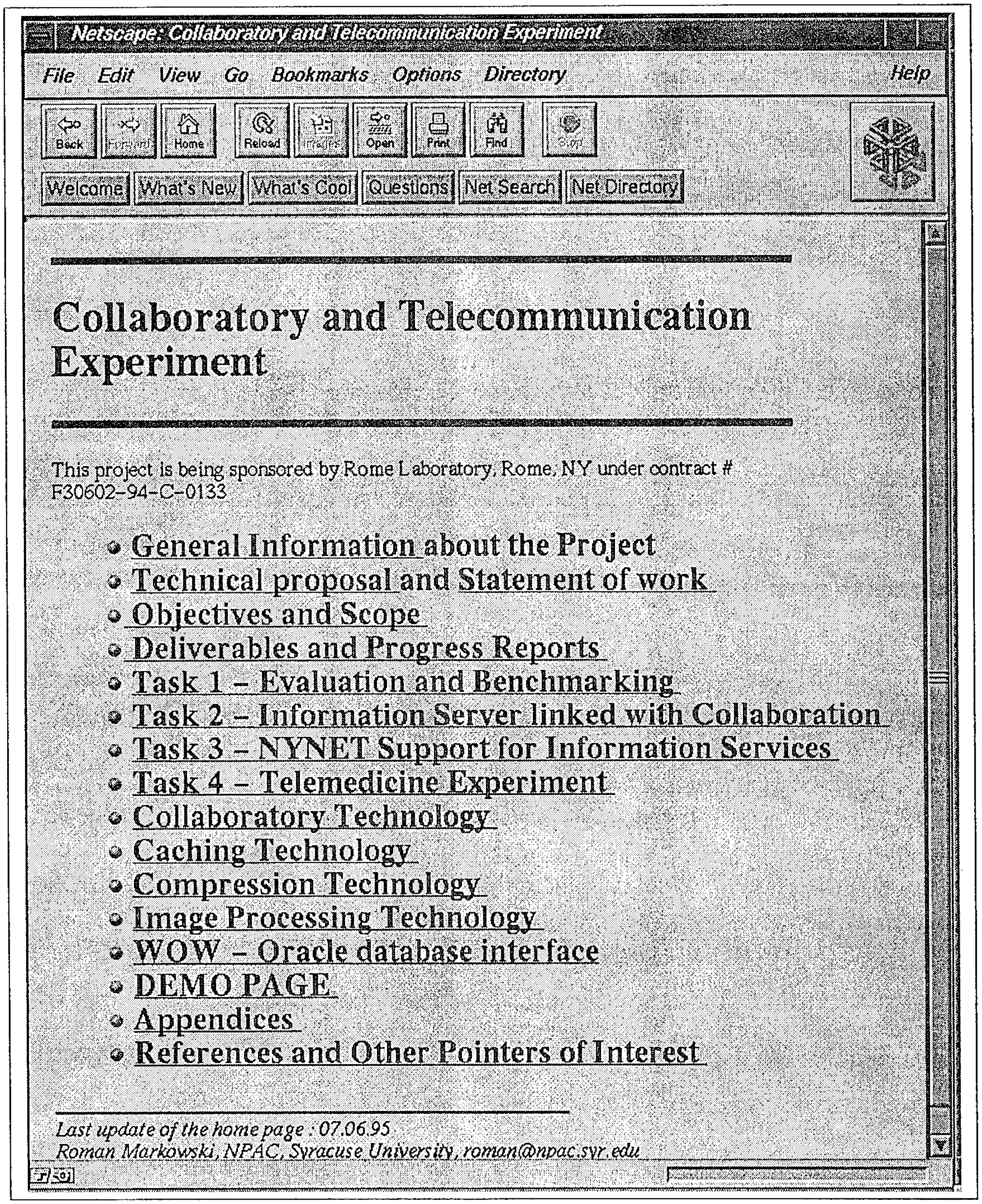

Figure 1: Project Information Server Home Page

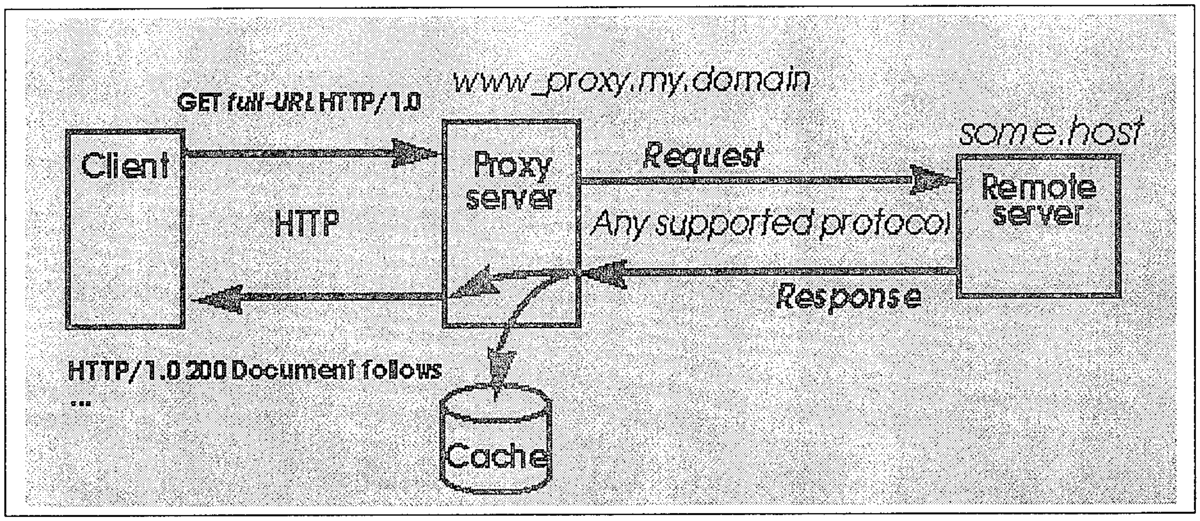

Figure 2a: Proxy Server - the requested document is retrieved from the remote server and stored locally on the proxy server for later use

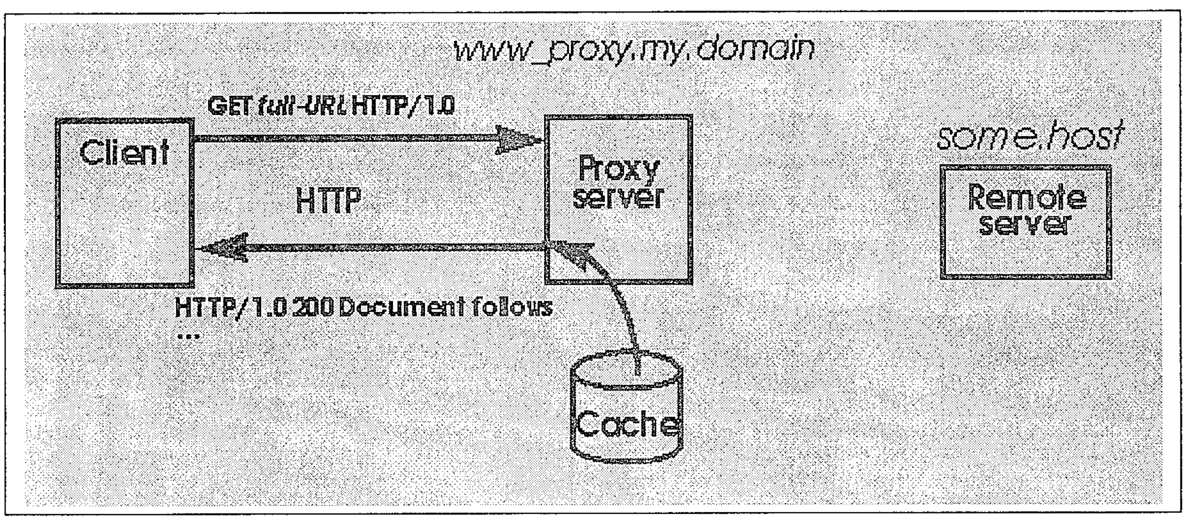

Figure 2b: Proxy Server - if an up-to-date version of the requested document is found in the cache of the proxy server, no connection to the remote server is necessary

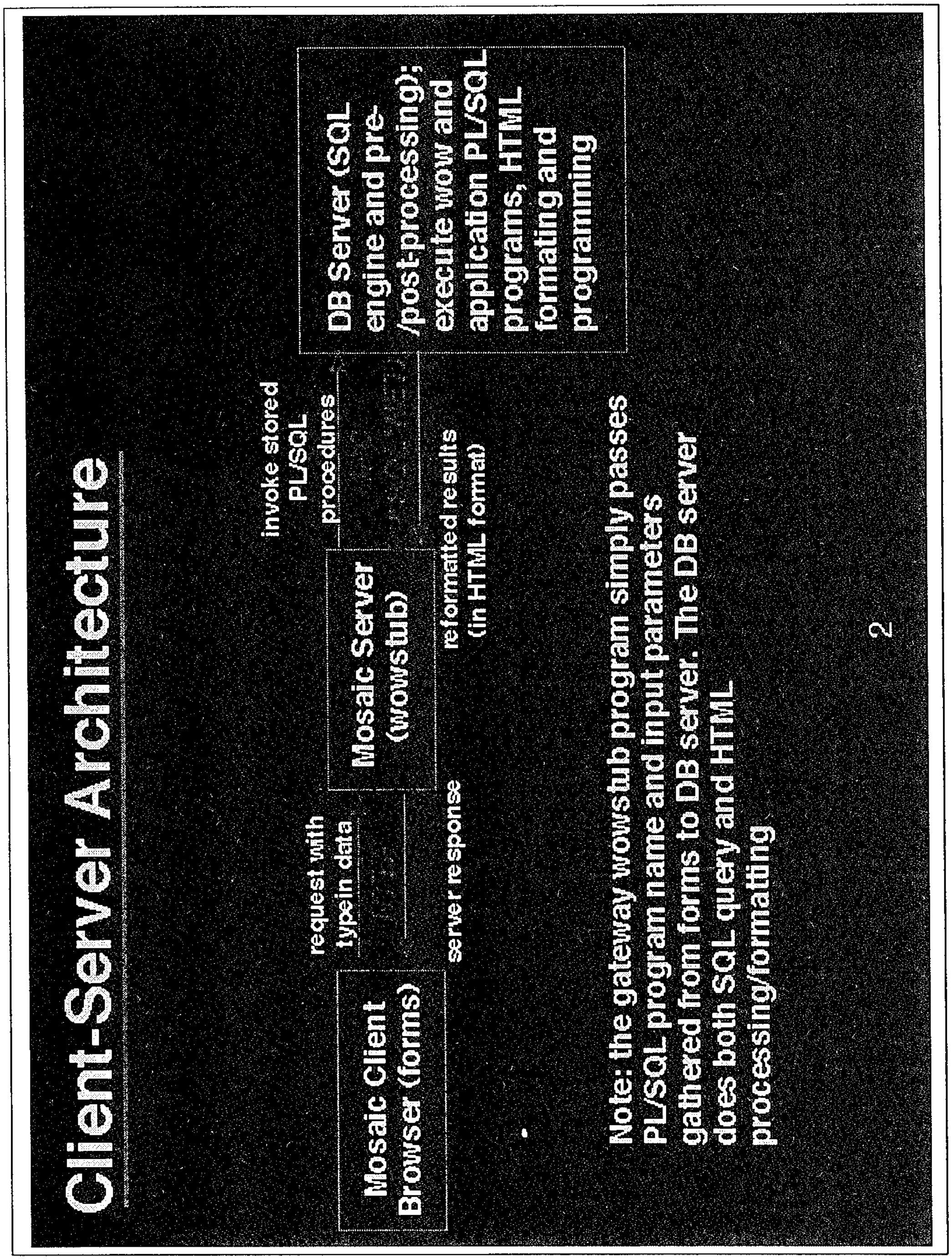

Figure 3: WOW - Client Server Atchitecture

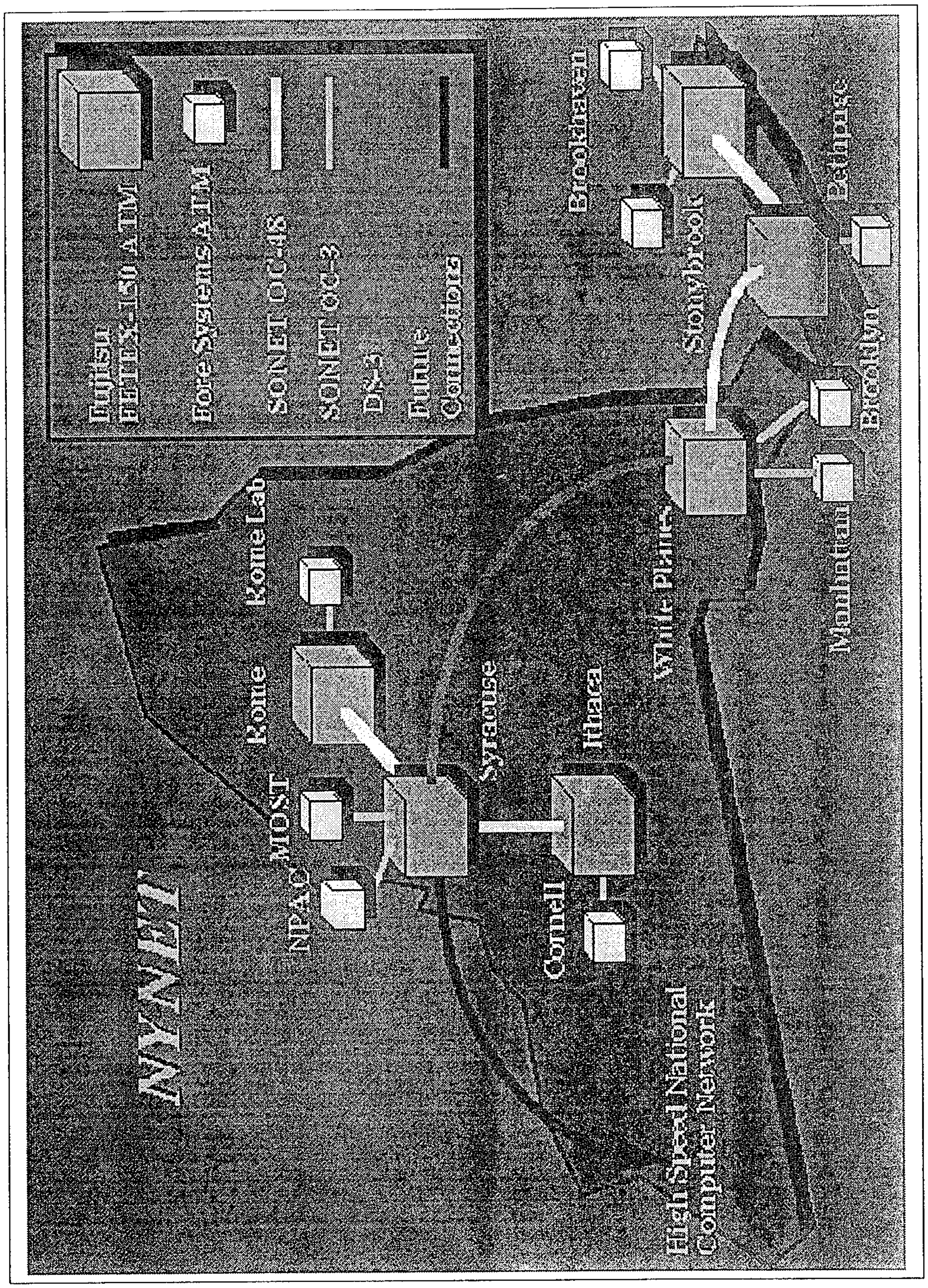

Figure 4 : NYNET Infrastructure

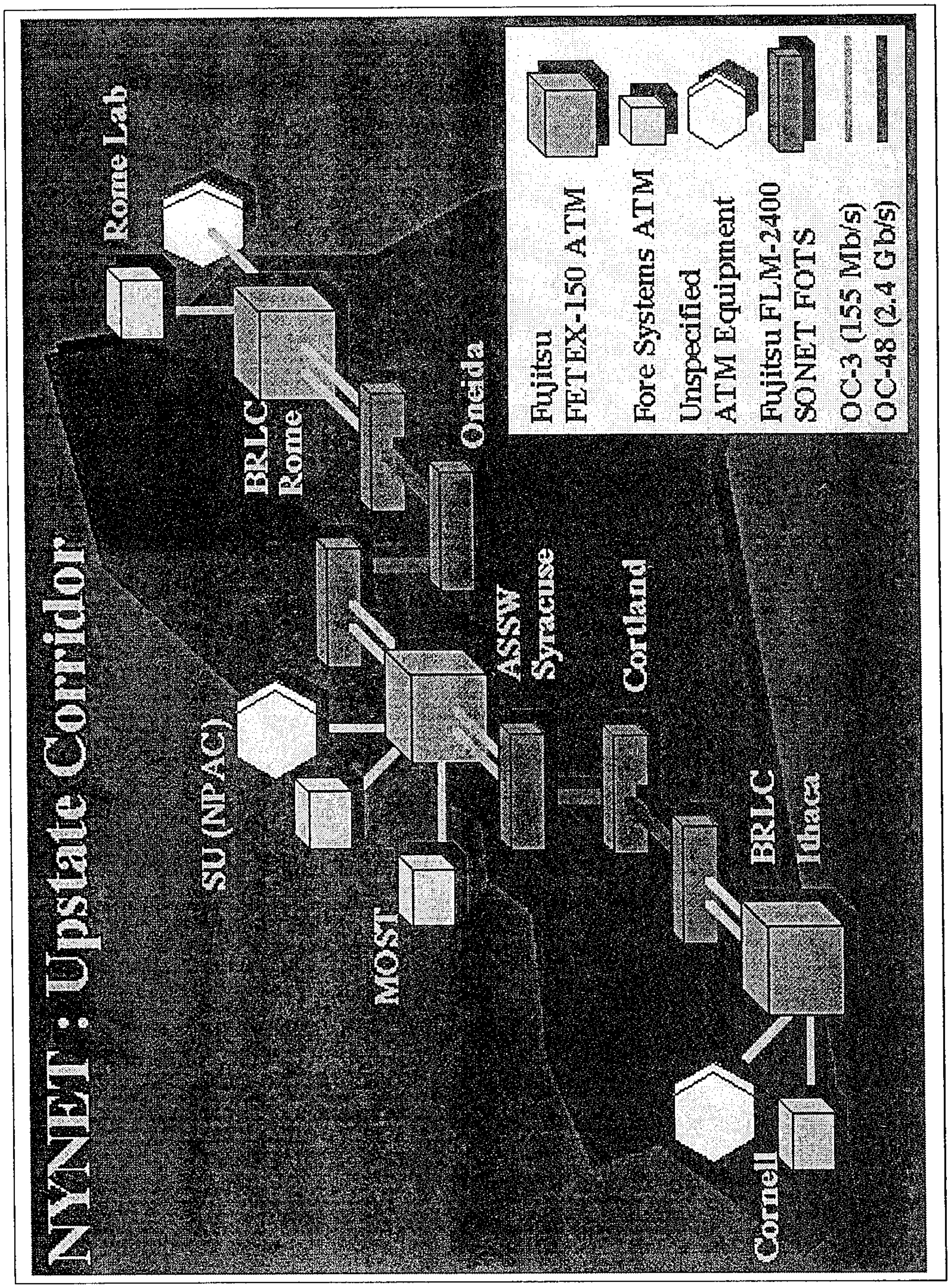

Figure 5 : NYNET - Upstate Corridor

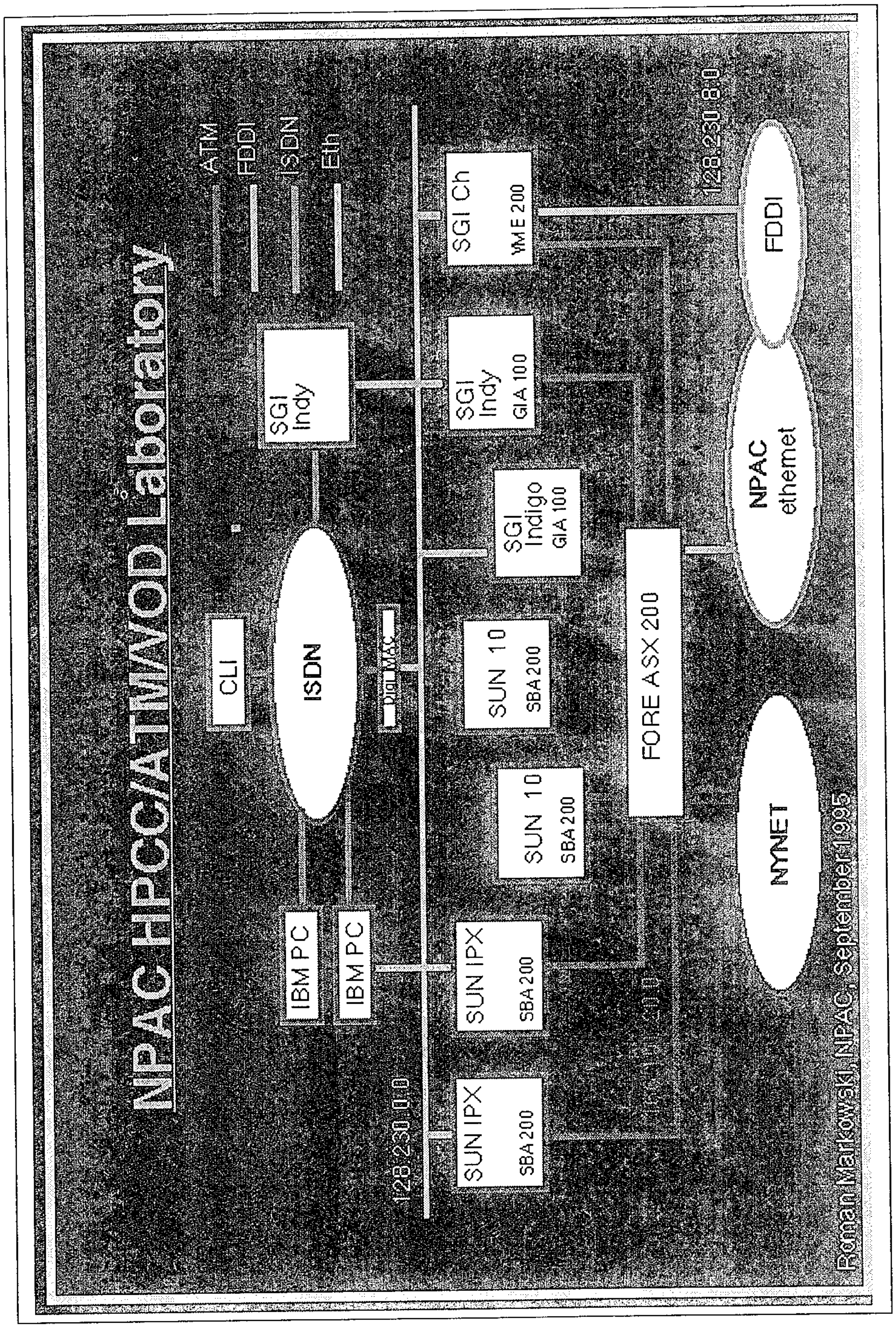

Figure 6: NPAC HPCC / ATM / VOD Laboratory

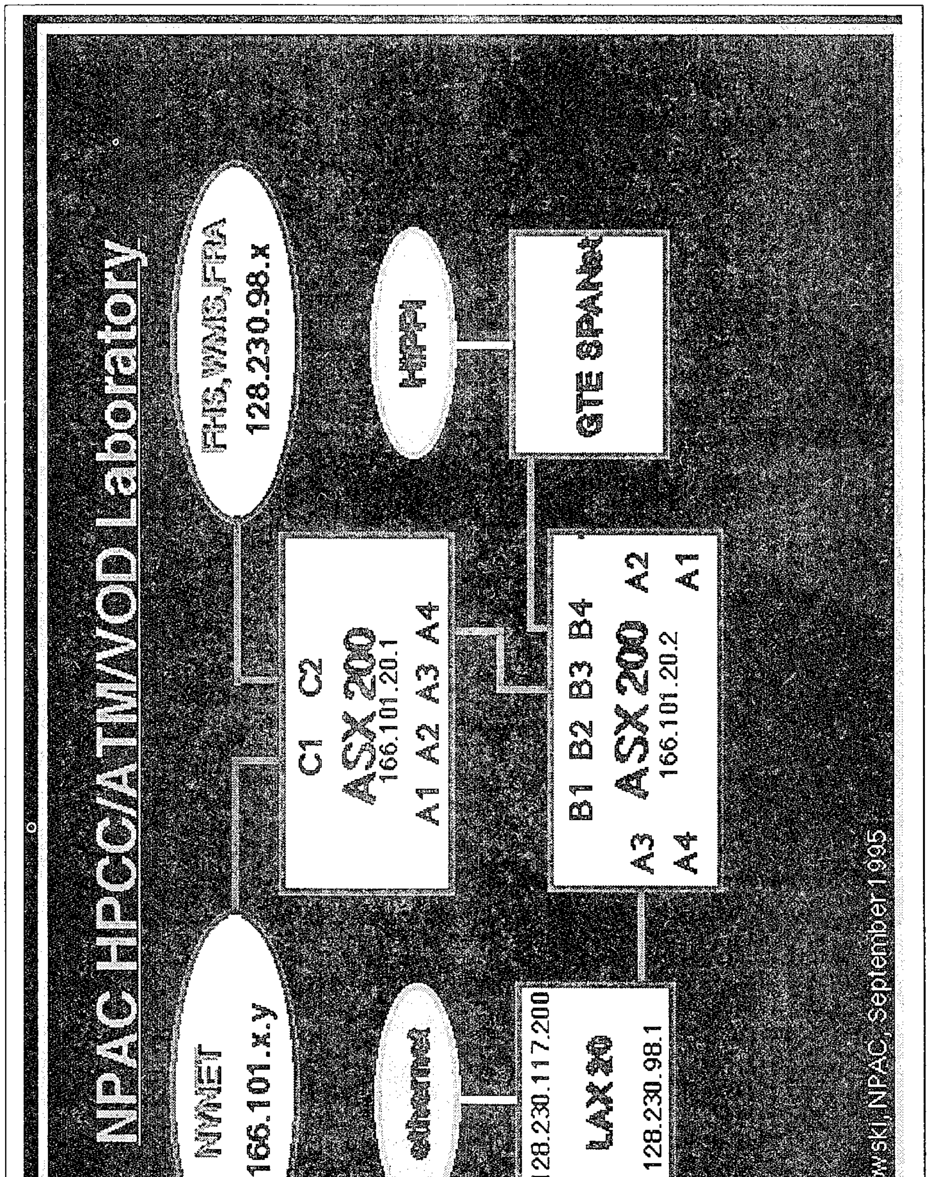

Figure 7: ATM Switches in NPAC

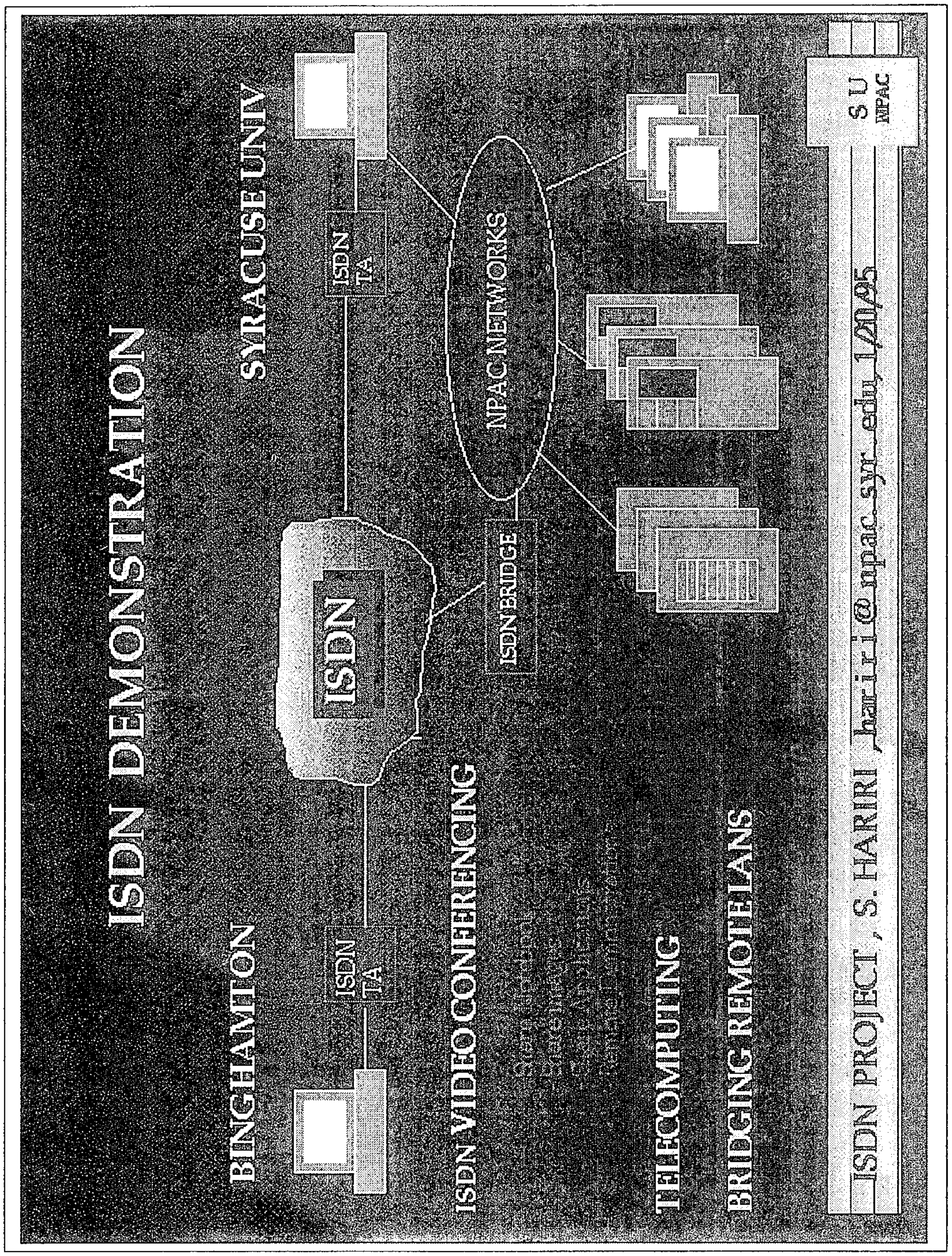

Figure 8 : ISDN Demonstration

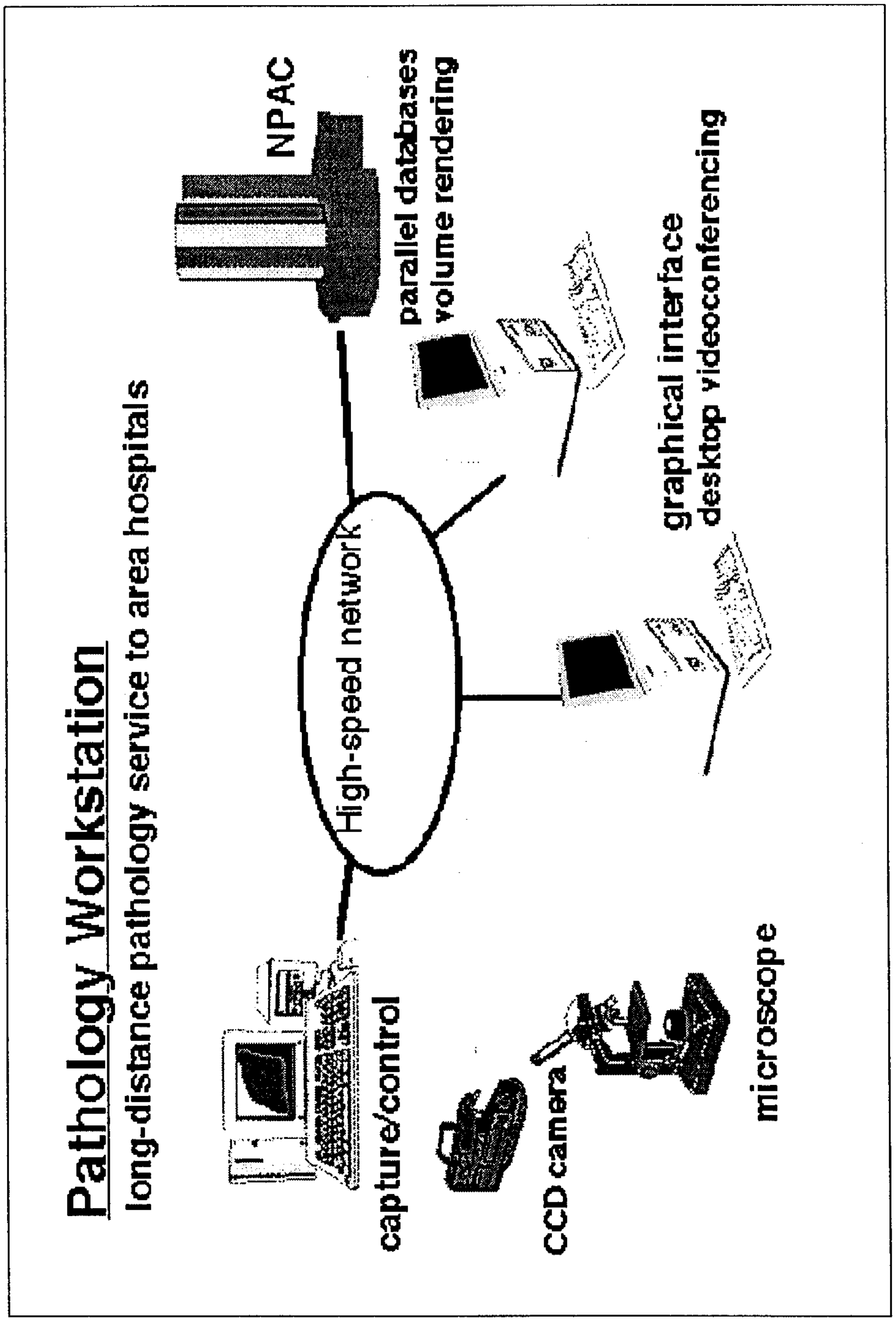

Figure 9 : Pathology Workstation

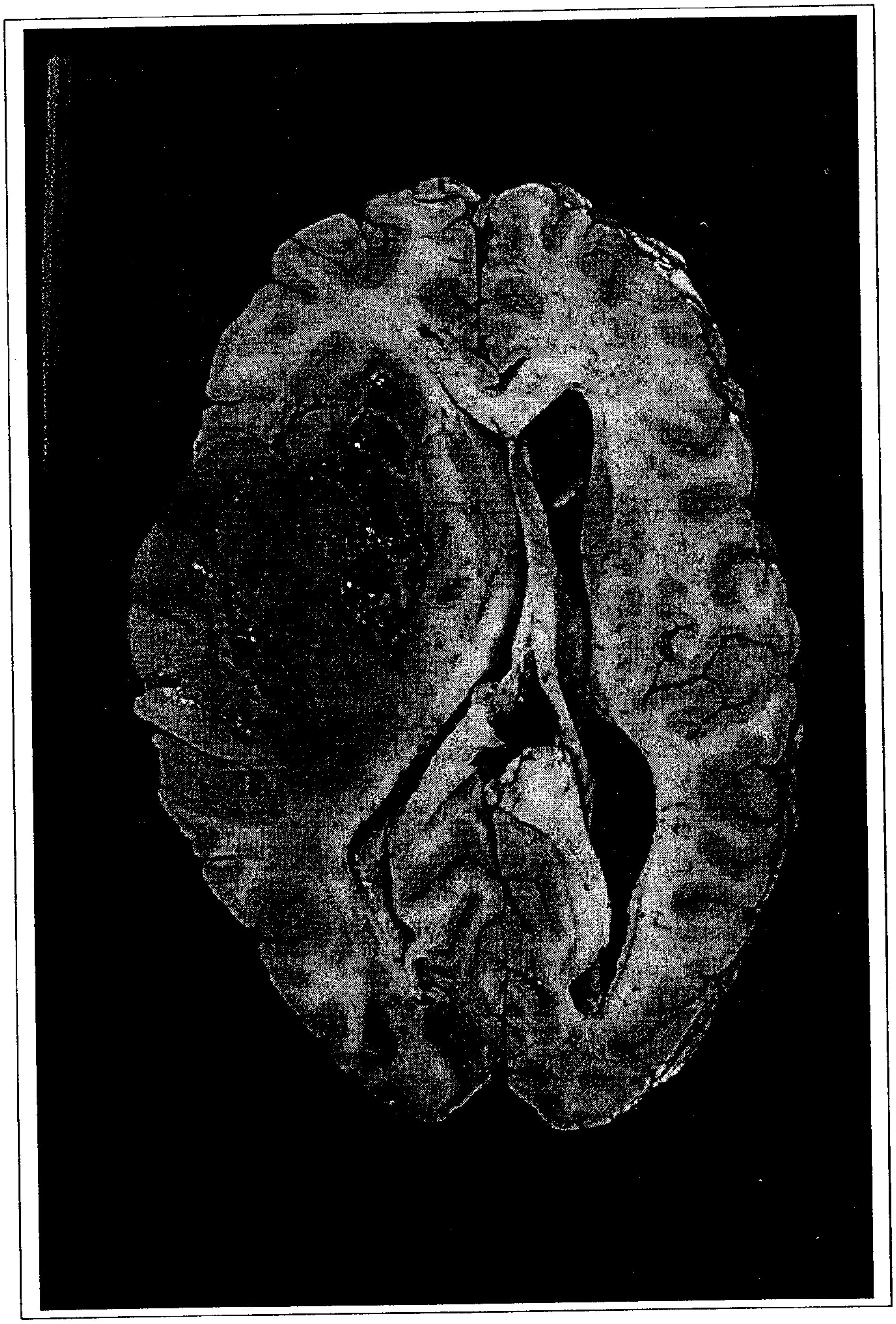

Figure 10 : Brain Tumor

Figure 11 : Typical Pathology Image

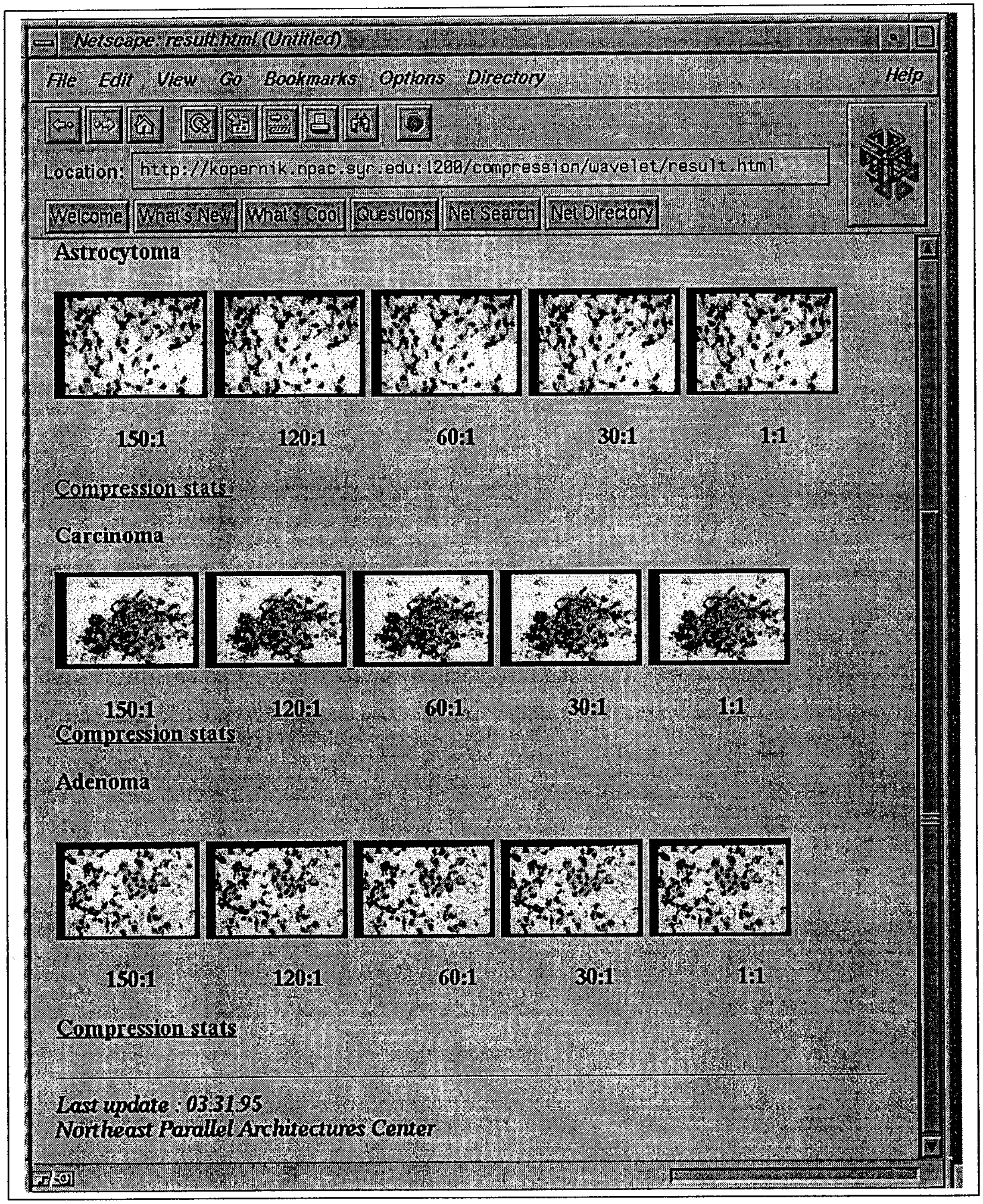

Figure 12 : Wavelet Compression of Pathology Images

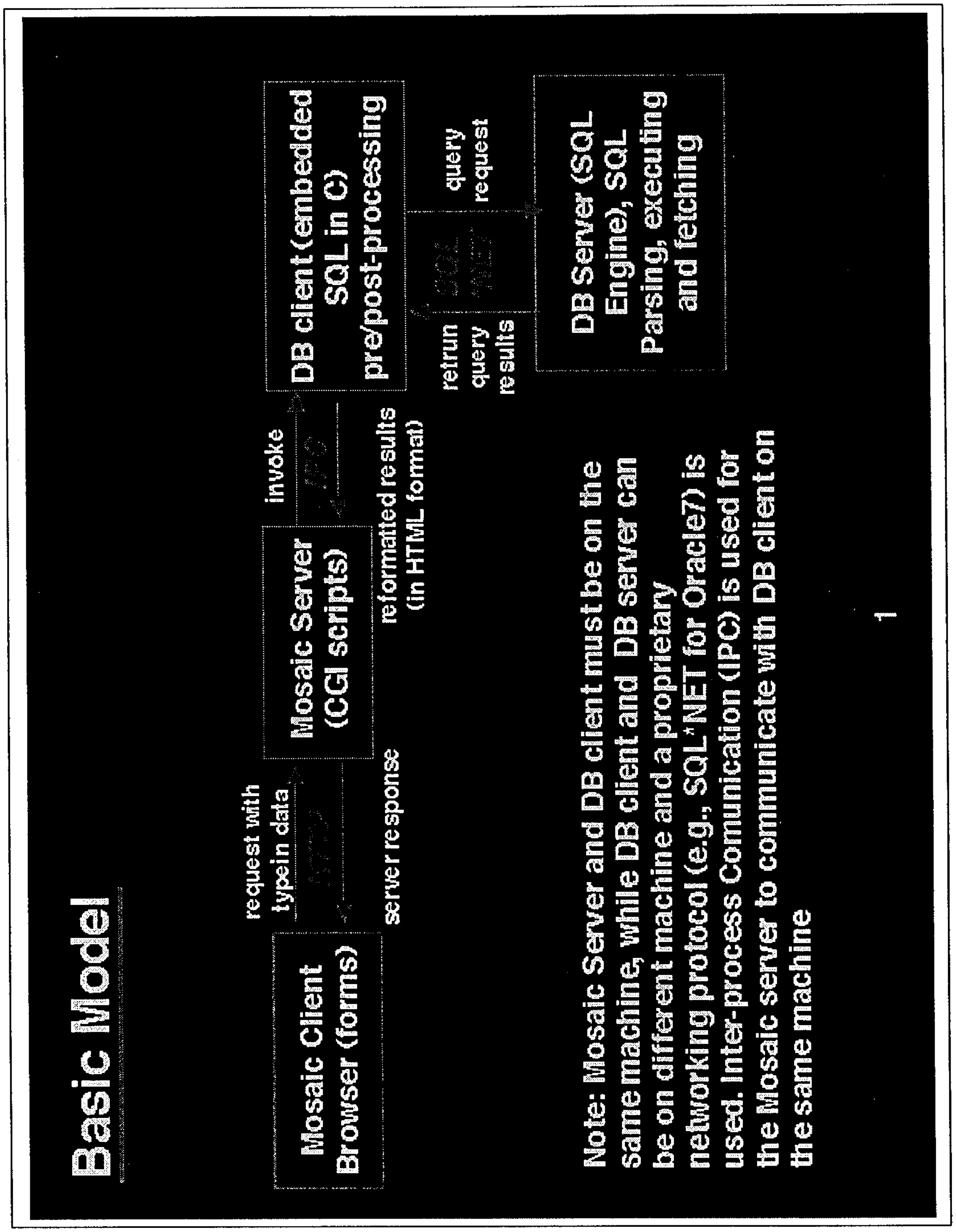

Figure 13 : WOW - The Basic Model

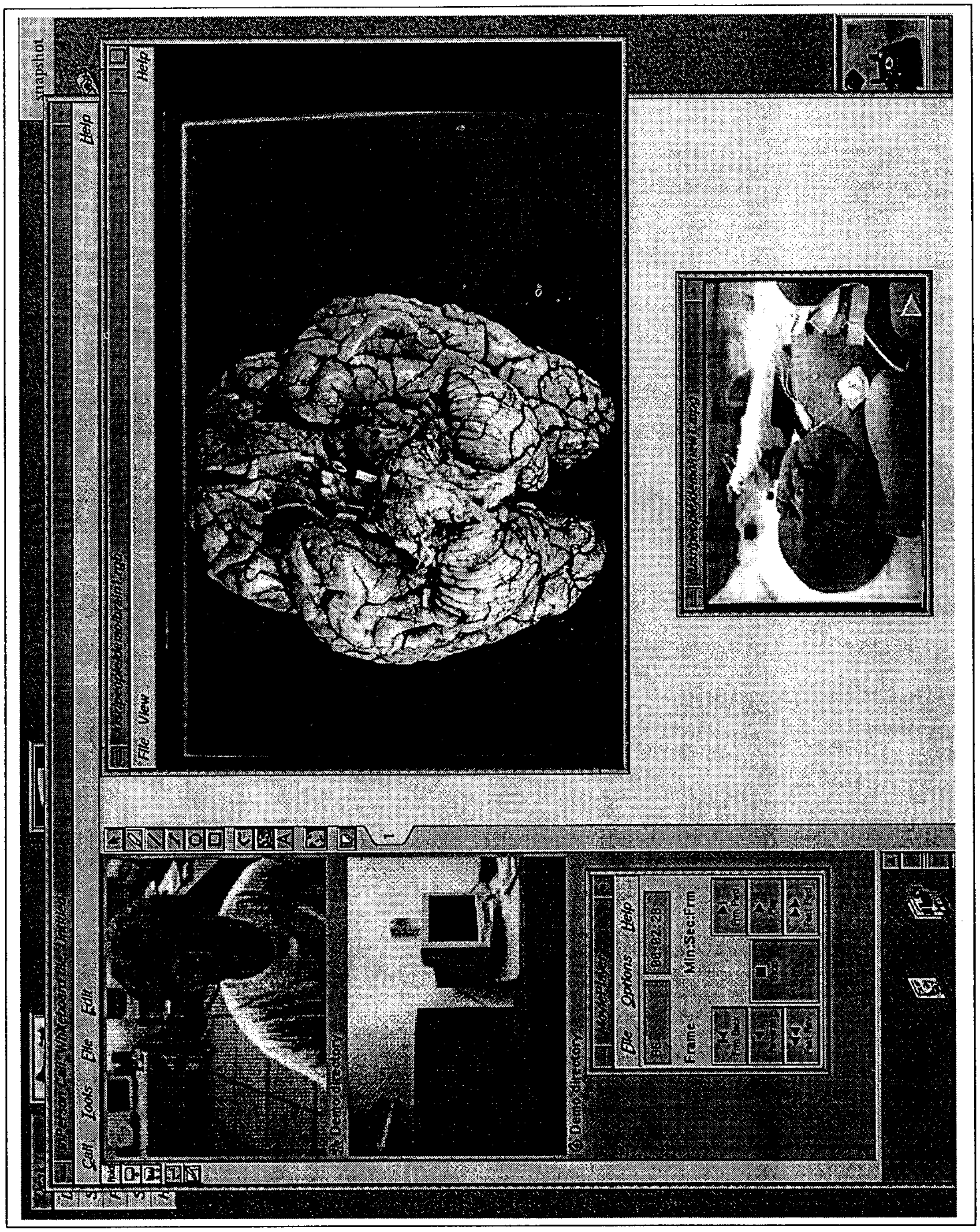

Figure 14 : InPerson Desktop Conferencing for SGI Workstation

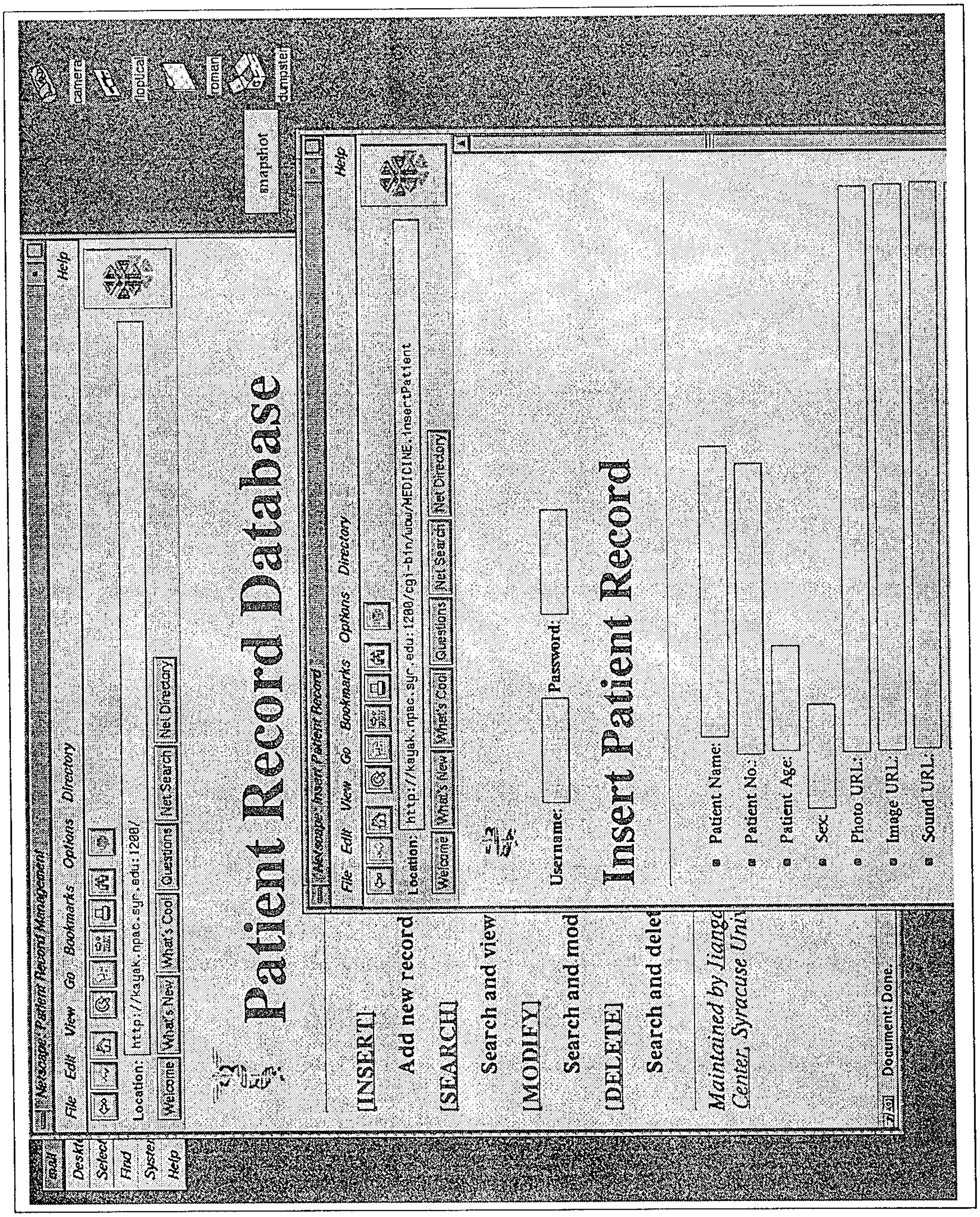

Figure 15 : Patient Record Database

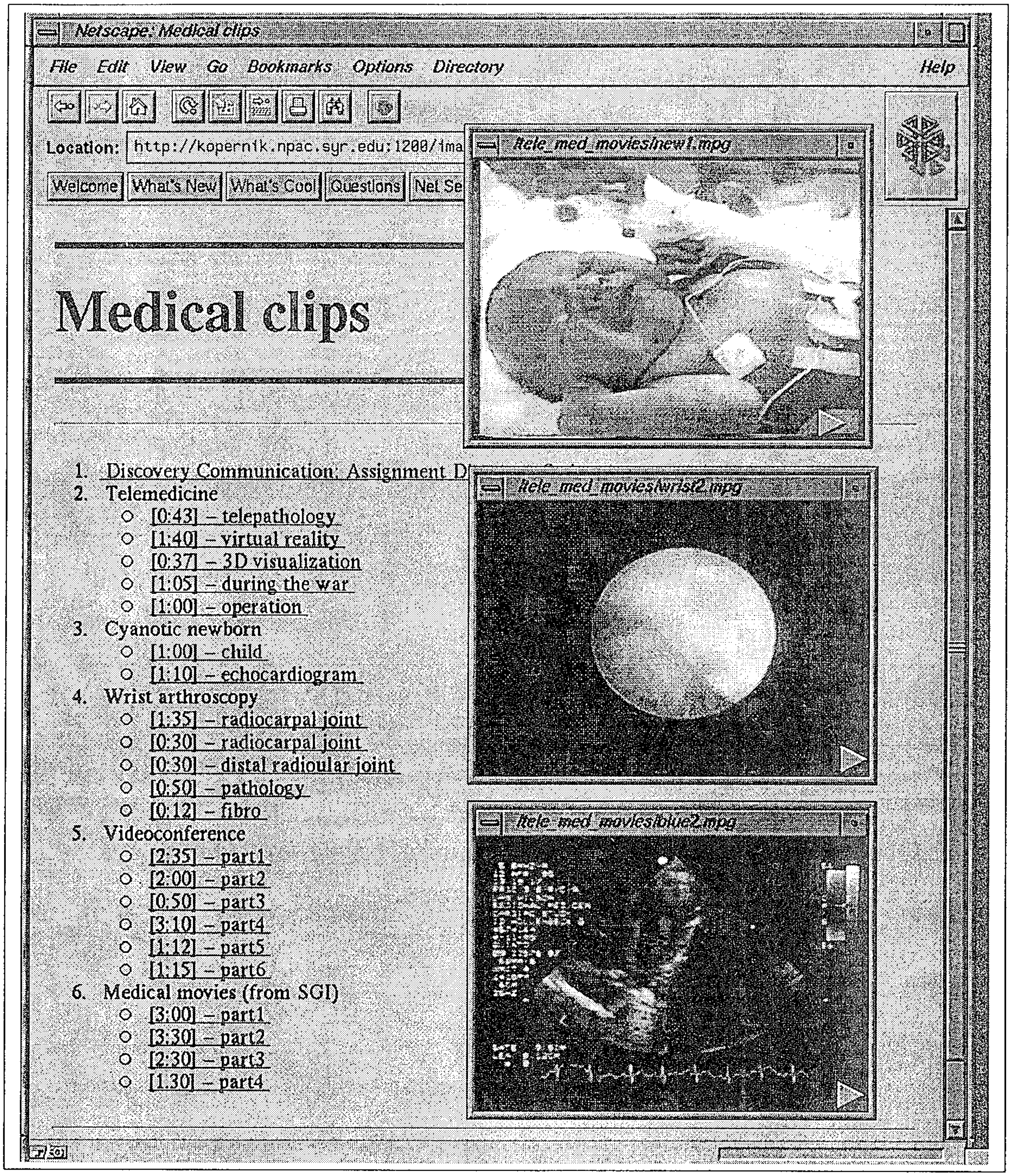

Figure 16 : Medical Videoclips

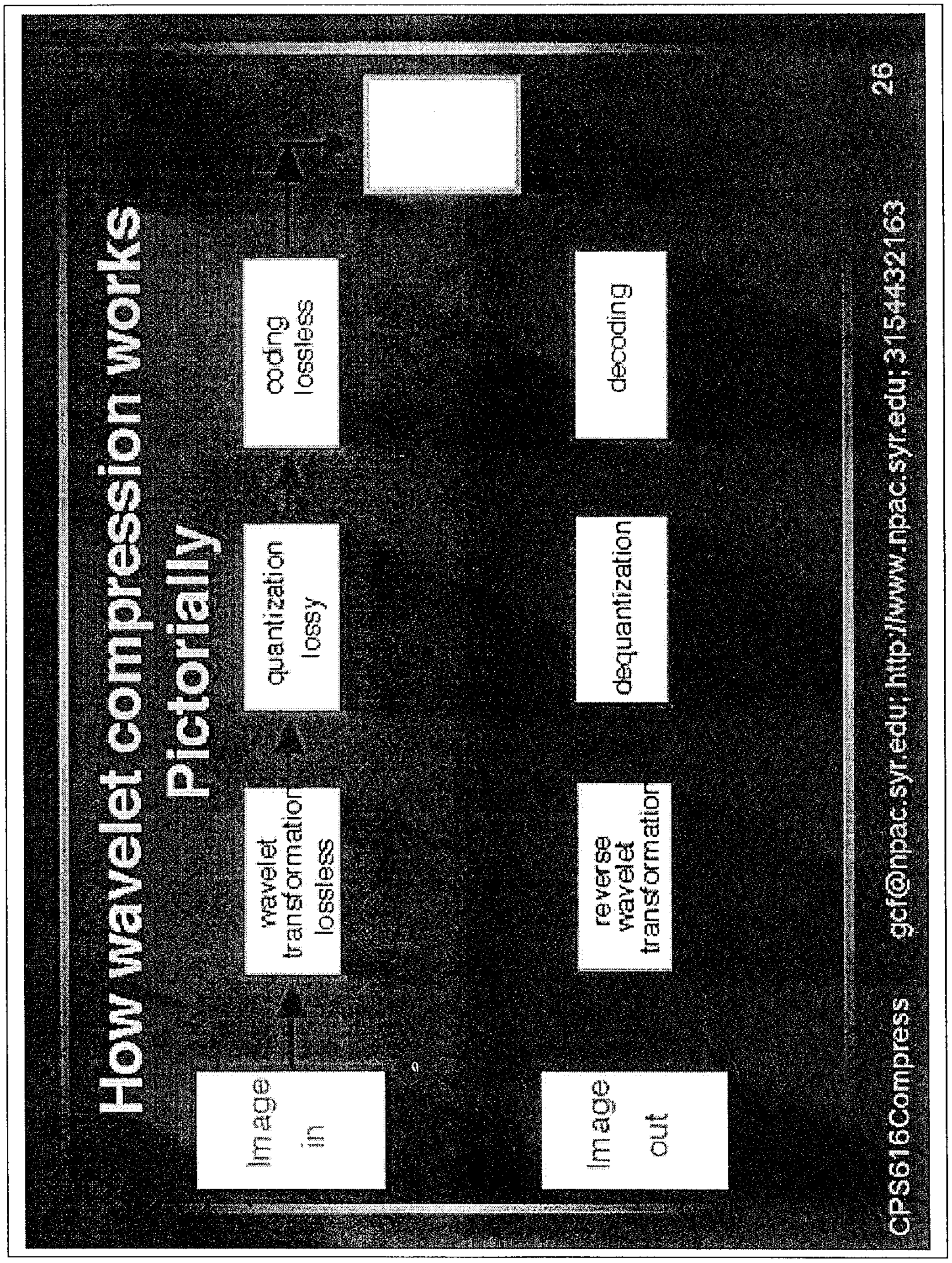

Figure 17 : How Wavelet Compression Works

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